ILLINOIS NATURAL HISTORY SURVEY

Barge Effects on Channel Catfish

Final Report, F-74-R

Center for Aquatic Ecology

Brian L. Todd, Frank S. Dillon, and Richard E. Sparks

July 1989

Aquatic Ecology Technical Report 89/5

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Federal Aid Project F-74-R

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by

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DISCLAIMER

The findings, conclusions, and views expressed are those of the researchers and should not be considered as the official position of the United States Fish and Wildlife Service or the Illinois Department of Conservation.

ABSTRACT

We implanted radio transmitters in 38 channel catfish in 1987 and 48 in 1988 to monitor the effect of commercial navigation on their behavior and to gather information about their habitat use and movements. High mortality (50%) after surgery was encountered in 1987 but technique and timing were corrected in 1988 and mortality decreased to 10%. Transmitter expulsion rates were estimated to be 37%.

During the period when locks were closed in 1987, (14 July to 7 September) habitat selection under two water level regimes was observed. During low flow, usage of main channel increased but was not a preferred habitat. During high flow usage of main channel declined. Temporary backwaters were used as soon as water levels made them accessible to the channel catfish. Side channel habitat was preferred prior to, and during lock closure. Following the resumption of tow traffic, as water temperatures decreased and water levels receded, usage of main channel and main channel borders increased.

Side channel habitat was preferred in spring and summer. Main channel border was preferred in fall. Main channel was used more in fall and winter but was not used in the proportion it was available. Side channels and backwaters were preferred in a winter with fluctuating water levels. Use of backwater habitats declined in 1988 when the low water levels made these areas unsuitable.

Channel catfish generally avoided navigated areas (main channel) and selected side channel and main channel border habitats. There was

no difference in selection of habitat between day and night. Depths between 3.4 and 6.6 ft were selected in greater proportion than they were available in the intensive study area in the summer.

A portion of the radio-tagged population was sedentary with 45% of our radio-tagged fish exhibiting net movements $\leq$0.11 mi. The maximum movement recorded was downstream 27.4 mi. Movement peaks were in the summer of 1987 and in late spring/early summer in 1988 and were also associated with fluctuations in water levels. Diel movements peaked between 1600-2400 hours. Movement increased during the period of lock closure.

Channel catfish exhibited movement averaging 80 ft in response to 52% of the tow passages monitored. When a detectable movement was observed, the distance moved was positively related to the number of units in the tow. Channel catfish > 131 ft from the tow moved during tow passage more often than those $\leq$ 131 ft, probably because the drawdown effect created by passing tows had more effect on the fish in shallow water.

Average depths selected in spring and summer (7.25 and 6.5 ft respectively) were shallower than average depths selected in fall and winter (8.5 and 8.4 ft respectively). Bottom current velocities at fish locations differed between seasons but not between day and night. Highest velocities were selected in spring (0.59 ft/s) and lowest velocities in summer (0.39 ft/s).

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ACKNOWLEDGMENTS

This work has been funded by the United States Department of the Interior, Fish and Wildlife Service, under the Dingell-Johnson/Wallop-Breaux Sport Fishing Restoration Program, project F-74-R, in conjunction with the Illinois Department of Conservation. Illinois Department of Energy and Natural Resources granted funds to purchase the initial set of transmitters, a receiver, and an antenna.

Dr. Richard E. Sparks wrote the original proposal, hired project staff and was the principal investigator for the project. Doug Blodgett contributed to the original project planning, assisted in writing the project proposal, assisted in field work and gave critical and valuable advice throughout the project. Vince Scott assisted with field work, maintenance and data entry from April 1988 to September 1988. Eric Hopps assisted with field work, maintenance and data entry from September 1988 to February 1989. Scott Stuewe, Illinois Department of Conservation piloted the tracking airplane in the first year of the study.

Dean Richardson, commercial fisherman, initially caught most of the channel catfish we radio tagged and he released many radio-tagged fish he captured in his routine fishing efforts.

We would like to thank Paul Raibley, Phil Moy, Dave Douglas, Jack Grubaugh, Alan McLukie and Steve Stenzel, Illinois Natural History Survey, Havana for there help with field work. Millie Watson typed portions of this report. We are indebted to the following Illinois Department of Conservation employees: Dale Burkett, Steve Gonzales,

for administrative support, Rudy Stinauer, Kenny Hills, Dale Bressler, Larry Munsch and Whitney Sarff of the Fisheries Field Headquarters in Havana for their guidance, use of facilities, and assistance, Rod Horner and Larry Durham, Jake Wolf Memorial Fish Hatchery for diagnostic work, and Dan Sallee and Elmer "Butch" Atwood, Streams Program for field assistance and valuable input throughout the study.

INTRODUCTION

The impacts of commercial navigation on the fishery resources of navigable rivers are largely unknown. The physical effects of tow passage have been documented (Sparks et al. 1980; Bhowmik et al. 1981a; Bhowmik et al. 1981b; Lubinski et al. 1981; Smart et al. 1985; Killgore et al. 1987). These investigators found that propeller wash and waves from tows create extreme shear forces, increase levels of suspended sediment for 2 to 4 hours after passage, reverse currents and temporarily draw down water levels. Smart et al. (1985) reported suspended solids increased 3.4% to 15% above ambient following tow passage on the Upper Mississippi River, and remained above ambient for up to 2.5 hr. Tow passage causes levels of suspended sediments to be raised up to 10% above ambient levels even in side channels (Bhowmik et al. 1981b; Simons et al. 1988). However, Simons et al. (1987) report the amount of sediment resuspended by tows has "little or no effect on the natural life of backwater areas and side channels". Herricks et al. (1982) found an increase in the macroinvertebrate drift immediately following tow passage due to disturbance of the substrate.

Previous research to document direct effects of tow passage on fishes has focused on the early life stages. Holland (1987) found that dewatering through the drawdown effect increased the mortality of walleye (*Stizostedion vitreum vitreum*) and northern pike (*Esox lucius*) larvae. Shear forces cause mortality to freshwater drum (*Aplodinotus grunniens*) eggs (Holland 1986), paddlefish (*Polyodon spathula*) yolk-

sac larvae (Killgore et al. 1987) and to striped bass (*Morone saxatilis*) and white perch (*M. americana*) eggs and larvae (Morgan et al. 1976). The waves generated by tows also change the vertical and horizontal distribution of ichthyoplankton (Holland 1986).

Resuspension of sediments contribute to the turbidity in the Illinois River. Buck (1956) reported that largemouth bass (*Micropterus salmoides*) in Oklahoma ponds and reservoirs failed to spawn at turbidities greater than 84 Jackson Turbidity Units (JTU) - a level exceeded for 2 hours following passage of tows in the lower Illinois River (Sparks 1977). Spawning success of redear sunfish (*Lepomis microlophus*) and bluegill (*Lepomis macrochirus*) was severely restricted or completely restricted above 100 JTU (Buck 1956). Tow-induced turbidities greater than 100 JTU persisted for over an hour in the Lower Illinois River (Sparks 1977).

Habitat degradation such as channelization, closing of side channels and dredging for channel maintenance has also had a negative impact on the fisheries of navigable rivers (Funk and Robinson 1974; Groen and Schmulbach 1978; Sparks et al. 1979; Karr et al. 1985; Hesse 1987). Although the navigation dams have expanded the quiet-water habitat available for some species during periods of low flow, some of the dams have created obstacles to the migrations of some riverine species (e.g. American eel *Anguilla rostrata*, skipjack herring *Alosa chrysochloris*; Smith 1979). In addition, the expanded aquatic habitats are eventually degraded and lost through sedimentation. The reach of the Mississippi River impounded by the Keokuk Dam (Dam 19)

will have changed from a pool to a relatively deep, narrow main channel bordered by mud flats and marshes by the year 2020 (Bhowmik et al. 1986). Sedimentation has already reduced the value of backwaters for fish and wildlife habitat in the Illinois River and these areas will lose half of their remaining volume to sedimentation in 24-230 years (Bellrose et al. 1983).

OBJECTIVES

It is important to document the effects of existing levels of navigation on river fishes so that adverse impacts associated with navigation can be avoided or perhaps mitigated. Also, these mitigation costs, or unavoidable fishery losses should be factored into cost/benefit analyses of future plans for navigation expansion. This study was initiated in the spring of 1987 with these objectives: 1) document the effects of various levels tow of traffic on the movement and behavior of adult channel catfish (*Ictalurus punctatus*), 2) collect basic data on channel catfish movements and habitat use in a large river, and 3) recommend protective or mitigative techniques. If navigation adversely affects channel catfish populations or habitat, mitigation measures might include restoration of side channels which have silted in or have been filled with dredge spoil. Restoration of these areas may provide habitat where channel catfish could find protection from some of the direct effects of navigation.

METHODS

Approach

Our approach was that of an opportunistic field experiment. The United States Army Corps of Engineers (USACOE) closed the navigation locks at LaGrange and Peoria, IL (Figure 1) for repairs from July 14 to September 6, 1987, halting commercial navigation on a 78-mile stretch of the Illinois River. This allowed a unique opportunity to monitor movements and habitat use by channel catfish under several different levels of traffic. We predicted traffic levels between the dams, in La Grange Pool, would increase prior to the closure and then resume at very high levels after the locks reopened (Figure 2) as tow boat owners and shippers made up for lost time. We planned to document the impacts of increased traffic. We expected little or no traffic within the pool during lock closure because most traffic is inter-pool rather than intra-pool. Normal traffic levels were predicted for the summer of 1988.

We set out to radio-tag adult channel catfish prior to the locks closing in 1987 in order to monitor the fish at high traffic levels, then with no traffic, and finally with high traffic levels as the locks reopened. We hoped to determine whether fish would occupy the main channel if there was no commercial traffic and document the response of the fish to the passage of the first tows when the locks reopened. Channel catfish radio-tagged in 1988 were to be the reference group subjected to normal levels of traffic.

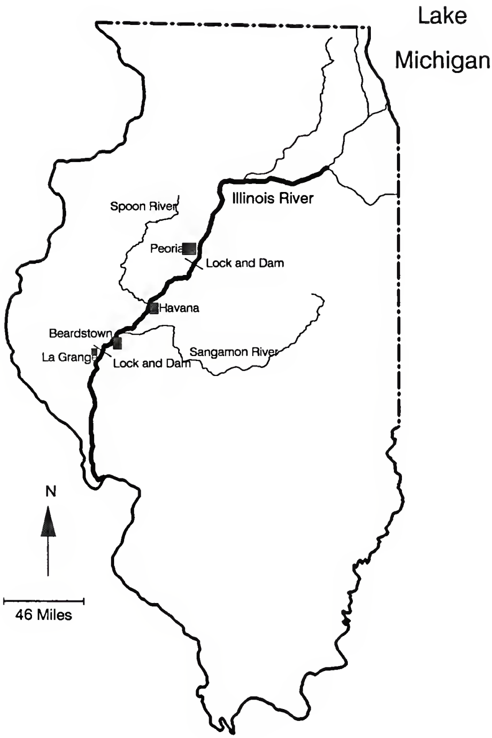


Figure 1. Map of the Illinois River system.

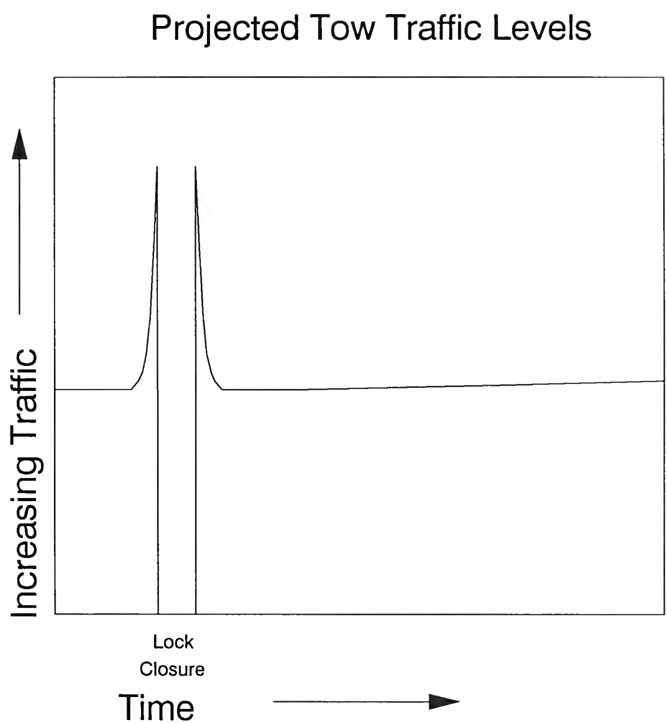


Figure 2. Predicted tow traffic levels in relation to lock closure.

Study Site

The Illinois River is a 8-9 order river that has a mean annual discharge of 21,106 ft^3/s at Havana, IL (USGS 1988). The River begins at the confluence of the Des Plaines and Kankakee rivers at Dresden, IL and flows 273 mi to join the Mississippi River at Grafton, IL. In 1871 the flow of the Chicago River was reversed and diverted into the Illinois and Michigan Canal to carry untreated waste away from Chicago's source of drinking water (Lake Michigan) and into the Des Plaines and Illinois rivers. In 1900 the Chicago Sanitary and Ship Canal was opened and large volumes of water were diverted from Lake Michigan to help flush sewage into the Illinois River. The effects of these pollutants on the biota in earlier years has been well documented (e.g. Richardson 1921; Starrett 1971; Sparks 1977; Sparks 1984).

The study site on the Illinois River is in the vicinity of Havana, IL (Figure 3) within the reach closed to commercial navigation. This area supports a commercial catfish fishery and two annual sport fishing derbies. This area also contains varied habitat types (main channel, main channel borders, side channels, backwaters and tributaries).

In contrast to earlier years, the dissolved oxygen and contaminant levels in the main channel of the study reach of the river today generally meet the Illinois water quality standards for general use, including protection of fish and wildlife (USGS 1988). However, the side channels and backwaters in this reach have filled with

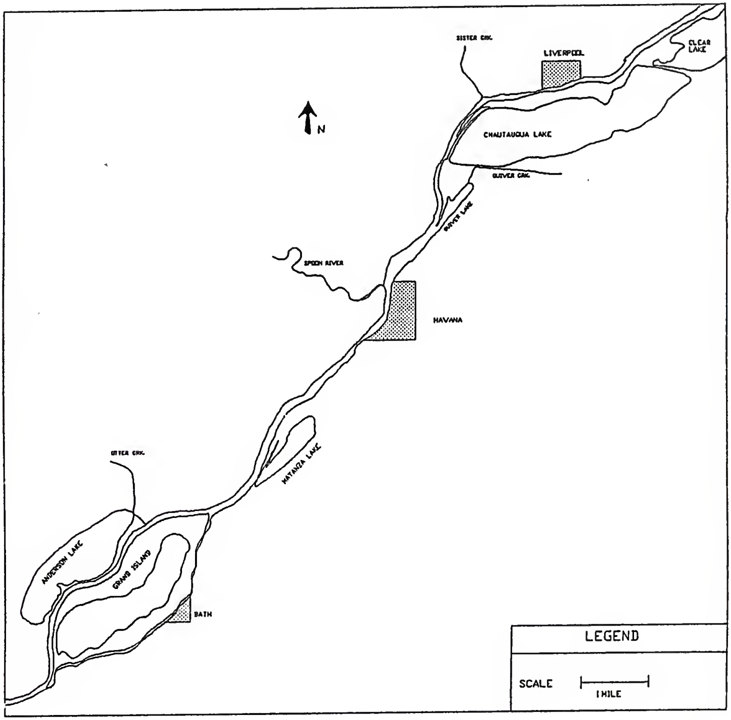


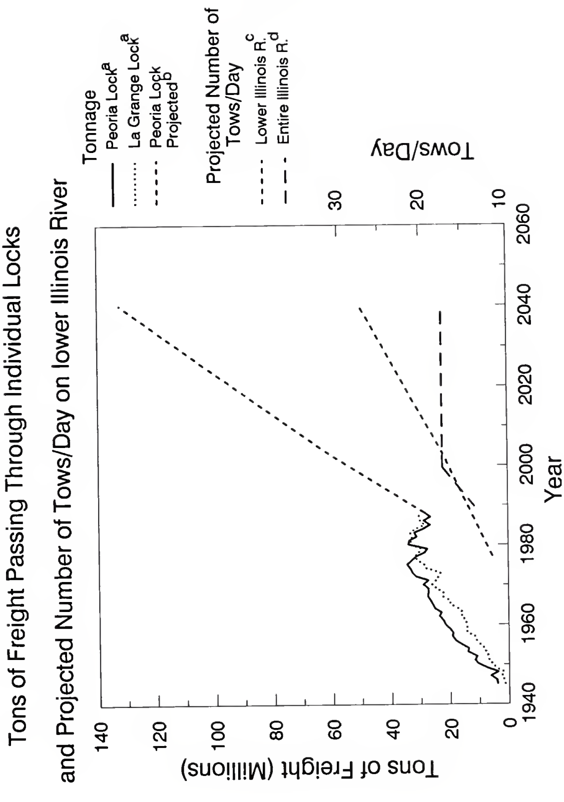
Figure 3. Map of study site.

sediment, which reduces the volume of habitat available to fish during low river stages characteristic of summer and early fall (Bellrose et al. 1983). The sediments are easily resuspended by wind- or boat-generated waves, hence submersed aquatic plants do not grow in the backwaters today probably because they cannot obtain a firm roothold in the loose sediment or sufficient light in the turbid water. Resuspended sediments also exert an oxygen demand on the water, so that waves often lower the dissolved oxygen concentration instead of aerating the water (Bellrose et al. 1977). The sediments also contain an unidentified toxic material which has drastically reduced the amount of animal food (mollusks and aquatic insects) available for bottom-feeding fish (Anderson et al. 1978; Sparks et al. 1981; Sparks and Sandusky 1983).

The Illinois River and the associated waterways link the Mississippi River, the Chicago area, and the Great Lakes. In 1988 over 30,000,000 tons of freight (e.g. grain, coal, petroleum) passed through the lock at La Grange, IL (USACOE 1989). Levels of commercial traffic are predicted to increase through the year 2040 (Figure 4) for both the Mississippi and Illinois Rivers, with completion of the additional lock and replacement lock and dam 26 on the Mississippi River 20 miles above St. Louis, MO (Louis Berger and Associates 1981; Simons et al. 1981; USACOE 1988).

Choice of Test Organism

The channel catfish is an important species in Illinois to both the recreational angler and the commercial fisherman. Thirty-nine percent of Illinois stream anglers seek catfish and catfish make-up



[a] USACOE 1989
[b] Louis Berger and Associates 1981
[c] Simons et al. 1981
[d] USACOE 1988

Figure 4. Actual and projected levels of commercial navigation on the lower Illinois River.

over 25% of total harvest from streams (Illinois Department of Conservation 1989). However, the effects of commercial navigation on channel catfish are largely unknown. Potential impacts of navigation on channel catfish need to be documented so mitigation can be planned. The channel catfish was chosen as the study organism because of its popularity with recreational anglers, and results from the study of its behavior may be generalized to some extent across a guild of big river catfishes (e.g. flathead catfish, *Pylodictis olivaris* and blue catfish, *Ictalurus furcatus*). Their tendency to use navigated areas (Hawkinson and Grunwald 1979; Stang and Nickum 1985) as well as off-channel areas may make them more vulnerable to the effects of navigation than fishes that are more frequently found in off-channel areas (e.g. crappies, *Pomoxis* sp., and bluegill; Sylvester and Broughton 1983).

Tagging

We radio tagged 38 channel catfish that were collected from main channel, main channel border and tributary habitats within the study area in 1987 and 48 from side channel, main channel, and main channel border habitats in 1988. Radio transmitters were surgically implanted into the abdominal cavity using procedures modified from Hart and Summerfelt (1975) and Bidgood (1980). The transmitters had external "whip" antennae for greater range. Two sizes of transmitters were used: one weighed 0.9 oz and had a life expectancy of 7 months and the other weighed 0.6 oz and had a life expectancy of 5 months. When using a 4-element YAGI receiving antenna, both types had a

broadcasting range of approximately 1,200 ft when the fish was in water 6 ft deep.

Transmitter weight was limited to $\leq$ 2% of body weight to avoid influencing fish behavior (e.g. Winter 1983). Limiting the transmitter-to-body-weight ratio also reduces the frequency of transintestinal expulsion -- a process where the intestine of a fish engulfs the transmitter and expels it through the anus. This phenomenon is particularly frequent in channel catfish (Marty and Summerfelt 1986, 1988). Studies indicate that the frequency of transintestinal expulsion in channel catfish can be reduced by keeping the transmitter weight $\leq$ 1% of the body weight (Summerfelt and Mosier 1984; Marty and Summerfelt 1986, 1988). We were forced to exceed the $\leq$ 1% criterion due to transmitter availability and design constraints as well as availability of large fish.

There have been several investigations showing that properly sized and placed transmitters do not have long-term effects on the behavior and swimming ability of telemetered fish when compared to control fish e.g. Gallepp and Magnuson (1972), McCleave and Stred (1975), Fried et al. (1976) and Crumpton (1982). Summerfelt and Mosier (1984) concluded that there was no difference in survival and growth of dummy-radio-tagged and non-radio-tagged channel catfish. Short-term effects have been documented, however. Hart and Summerfelt (1973) found flathead catfish moved more for 1.5 days following surgery. Conversely, McCall (1977) found channel catfish moved less the first day after surgery and suspected their movements were restricted for several days. For this reason, radio locations made $\leq$

7 days following surgery were not used in the analysis.

Radio-tagged fish were located at least twice weekly by boat in summer, once weekly in spring and fall and 2 to 3 times per month in winter. We used a scanning programmable receiver and maneuvered the tracking boat in a zig-zag pattern from bank to bank when searching for fish. This zig-zag pattern gave us maximum coverage of the main channel. Once a fish was located, its geographic coordinates were determined using a Loran C navigation receiver interfaced with a Lowrance depth sounder.

Lost radio-tagged fish were located using an airplane equipped with telemetry receiving equipment. We made the flights at altitudes of 500 to 600 ft and an airspeed of 80 knots. Antennae and receiver configuration were patterned after Gilmer et al. (1981). We tried to keep the airplane over the navigation channel when searching the mainstem and flew transects over the backwater lakes.

We informed the public of the project and of the importance of returning each radio-tagged fish to the water and notifying us. We distributing press releases to local and regional newspapers, presented a brief project narrative in conjunction with local fishing derbies and invited members of the press to view surgical and fish locating demonstrations.

Physical-Chemical Measurements and Habitat Descriptions

Type of habitat and depth occupied were recorded each time a fish was located. Water temperature, dissolved oxygen, and current velocity were measured at the fish location approximately every third

time the fish was located. Dissolved oxygen and water temperature measurements were taken 0.5 ft. below the surface and 0.7 ft above the streambed. Current velocity measurements were made 0.7 ft above the streambed. We made the assumption the fish was on the streambed. Secchi disk transparency and conductivity were monitored in 1987 and 1988. Total ammonia concentrations and pH from the middle of the water column were measured in 1988 using a Hach^R kit and portable pH meter. These concentrations were corrected to provide un-ionized ammonia concentrations using an equation developed by Emerson et al. (1975). The Illinois State Water Survey conducted a comprehensive water quality investigation on the La Grange Pool in relation to the lock closures (Butts in prep.).

We used the standard guidelines established by the Upper Mississippi River Conservation Commission (UMRCC) for classifying riverine habitats.

The following definitions are modified slightly from Nord (1967).

Main Channel The portion of the river through which commercial craft can operate. It has a minimum depth of 9 ft and a minimum width of 300 ft. A current always exists, varying in velocity with water stages.

Main Channel Border The zone between the nine foot channel and the main river bank or islands. A current always exists, varying in velocity with water stages.

Side Channels Departures from the main channel and main channel border in which there is current during normal river stages.

Backwaters Bodies of water connected with the river during normal water stages. Backwaters may or may not have slight current.

Intensive Monitoring

Intensive monitoring periods of 8 to 54 hours duration were conducted with select fish located every 2-4 hours in 1987 and hourly in 1988 (Appendix A). These fish were selected on the basis of their proximity to each other and to the navigation channel. By selecting fish that were less than $\leq$ 1 mi from each other we could obtain more locations/fish/monitoring period. On 23 occasions, fish in main channel border and main channel habitats were monitored continuously immediately before, during and after a tow passed.

DATA ANALYSIS

The 24-hour day was divided into two periods to compare habitat and depth use between the two periods. Day extended from sunrise to sunset, and night sunset to sunrise. Seasonal boundaries were; spring 1 March-19 June, summer 20 June-30 September, fall 1 October-15 December and winter 16 December-28 February.

Habitat Use vs. Availability

Habitat use data are valuable but become more meaningful when presented in relation to the availability of the habitats. It is difficult to determine habitat availability values when the fish are distributed over 10-20 miles of a large river with fluctuating water levels. Fortunately the water levels were relatively stable for both years during the times we were monitoring fish.

The availability values used in the results sections entitled "Habitat Use in Relation to Lock Closure" and "Seasonal Habitat Use" were obtained by planimetrically measuring USACOE aerial photographs of the Illinois River Valley that were taken in 1979 and 1980. These photographs were complete with 2 ft elevation contours above the water surface. Proportions of the River considered main channel and main channel border were estimated by averaging proportions from 1987 USACOE soundings of the study reaches. The area of each habitat was measured based on a water surface elevation of 430.5 ft (flat pool elevation = 429.2 ft) and an elevation of 436.0 ft (the average water surface elevation at which fish were monitored during the 1987 summer flood). The availability estimates include inundated areas connected to the mainstem from river mile 119.9 to 131.6 for 1987 and from river mile 107.2 to 131.6 for 1988. The longer study reach was used in 1988 because the fish were more widely distributed. The last 1 mi of the tributaries, Spoon River and Quiver Creek, made up the tributary habitat area. The area of each habitat divided by the total surface area of the reach was the proportion of the habitat present and assumed to be available to the fish.

Strauss' index of linear selectivity (L) (Strauss 1979) was used to determine if a habitat or depth category was selected for or against.

$$L = \%\ \text{Used} - \%\ \text{Available}$$

L was calculated for each depth category and habitat. A value of +1.0 indicates high preference, a value of 0 indicates the interval or category is not selected for or against (used at random), and a value

of -1.0 indicates complete avoidance. Although traditionally used as an index of food selection, Strauss' index was chosen instead of Ivlev's selectivity index (Ivlev 1961) because Strauss' is a linear index and calculated values can be statistically compared.

Statistical Analysis of Use vs. Availability Data

In the summer of 1988, 8 radio-tagged fish resided in a 1.5 mile stretch of the study area (Figure 5). This subset of fish was monitored intensively and the data were used in a more detailed use versus availability analysis. With 8 fish and four habitats available, Alldredge and Ratti (1986) recommend a minimum of 15 observations/fish/period of interest to perform a similar type of analysis. Since we wanted to compare between night and day we limited our analysis to only those fish on which we had at least 15 observations during the day and 15 at night.

Surface areas of each habitat and depth category of the intensive study area were mapped using the transect method in late summer of 1988. Water levels during that time were comparable to those during the periods of intense monitoring, thus making the use data compatible with the availability data. The transects were 131 ft apart on average (56 ft minimum, 182 ft maximum). Depth along each transect was recorded continuously using a recording depth sounder. From the map, the area of each component was measured.

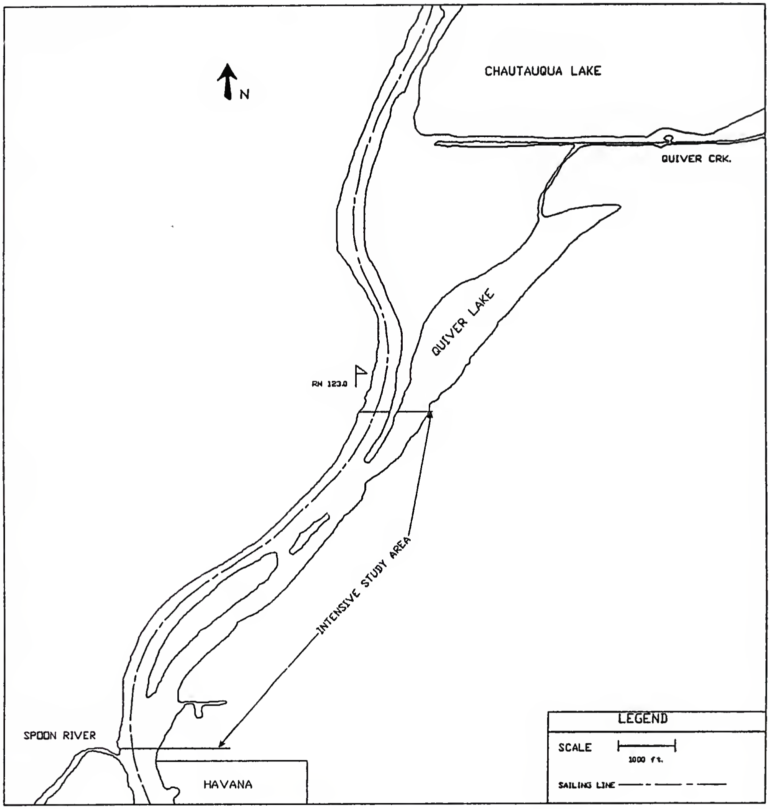


Figure 5. Map showing intensive study area of 1988.

The criteria for defining habitats (e.g. main channel is the portion of the river through which commercial craft can operate and has a minimum depth of 9 ft) violates the assumption that depth and habitat are independent. To overcome this problem of dependence we combined main channel and main channel border to make a habitat type, navigable channel, where all depths were available for comparison to a non-navigable channel (side channel) where all depths were also available.

A two-way ANOVA was used to test the L values between navigable channel and non-navigable channel and between time periods (alpha level= 0.05). This tested the H_0: there is no difference in selection and availability of habitats regardless of time period.

Velocity Utilization

Data collected in all seasons were used in the rest of the analyses. A two-way ANOVA was used to test the use of velocities between time periods and between seasons (alpha level= 0.05). If a significant difference was detected, Bonferoni's multiple comparison procedure was used to determine in which seasons velocity use differed significantly. An alpha level of 0.10 was used as the experimentwise error rate for all multiple comparisons. The higher alpha level was used because the pairwise error rate is the quotient of the experimentwise error rate divided by the number of pairs compared.

Movement

To analyze movements river mile was recorded to the nearest 0.1 at each fish location. Movements of less than 0.1 mi were noted on the data sheets. The absolute differences between consecutive

locations summed was the total (gross) distance traveled. Net movement was the difference between the final location and initial location. Positive values (+) indicate net upstream movement and negative values (-) indicate downstream movement. Diel movement patterns were determined by dividing the distance traveled between consecutive locations by the number of hours between the consecutive locations. In the analysis of diel movement we limited the analysis to locations recorded $\leq$ 4 hours apart in order to standardize comparisons between 1987 and 1988.

RESULTS

Mortality and Transmitter Expulsion

During late June and July of 1987 the radio-tagged channel catfish experienced unacceptable rates of transmitter loss and/or post-operative mortality. Fourteen of 25 implanted fish (56%) either died or expelled transmitters through the intestine or abdominal wall (as described by Marty and Summerfelt 1986). Four transmitters were found on shore above the high water line, leading us to believe the fish died and scavengers (opossum, raccoon) carried the carcass and transmitters up the bank. Fishermen found two carcasses. The mortality or loss of radio tags occurred from two to 45 days after surgery. Marty and Summerfelt (1986) reported expulsion of dummy transmitters by channel catfish as soon as 5 days following implantation.

The high mortality was of great concern. Low river stages, high water temperatures and low dissolved oxygen concentrations typical of summer all probably contribute to general fish mortality. Spawning, bacterial infections and surgical implants were additional physiological stresses experienced by our channel catfish.

We looked at these factors in an attempt to determine the cause of mortality. On 11 August 1987, two apparently healthy channel catfish were collected, implanted and placed in a 500-gallon tank of water from the Illinois River. Approximately 200 gallons of fresh river water was pumped in every other day. Water temperature was 79^{0} F and dissolved oxygen levels ranged from 6.8 to 7.5 ppm. Three days

after surgery one fish had developed an abscess just anterior to the incision; the other fish appeared to be healing. On the fourth day the abscessed fish was still alive even though the infection was spreading, and the apparently healthy fish died.

Necropsies were performed and bacterial cultures taken from each fish. Signs of intraperitoneal infection and septicemia were noted in the fish which died (Horner and Durham, Fish Pathologists, Illinois Department of Conservation, personal communication). In their opinions this fish succumbed to a bacterial infection it contracted before it was collected and would have soon died even without the stress of surgery. The abscessed fish also had a low grade systemic infection similar to that described above. The abscess was caused by an infection restricted to the musculature surrounding the incision. The infection that caused the abscess was probably introduced during surgery. The fish was immunologically unable to suppress two infections at once and would have died in several days. The bacterium *Aeromonas hydrophila* was identified as the causative agent. This bacterium is common in aquatic environments and infects weakened fish (Cipriano et al. 1984). Low dissolved oxygen levels, (such as those we recorded at night, 1.9-3.5 ppm), elevated water temperatures, and increases in ammonia levels stress fish enough to allow aeromonad septicemias to develop (Lewis and Plumb 1979; Cipriano et al. 1984).

Although *A. hydrophila* is ubiquitous in bodies of fresh water, it may be present in greater numbers in the Illinois River. Industrial and municipal effluents contribute significantly more to the base flow of the Illinois River than they do to other large rivers in the

Midwest. Some of these waste effluents may act as nutrient sources, causing some pathogenic bacteria (e.g. *A. hydrophila*, *Vibrio cholerae*) to be present in higher than normal levels (Grimes et al. 1986).

Modifications to Surgical Procedure

We modified our surgical procedures in an effort to reduce handling stress and risk of infection. In mid-August 1987, 10 fish were captured and held for 24 hours in aerated well water that had warmed to 75^{0} F. The water was treated with salt (NaCl) to adjust the salinity to 0.5% to compensate for osmotic imbalances caused by the stress of capture and holding. Even though holding feral fish for any period of time causes stress, we felt that the benefits of stable dissolved oxygen levels and cool, relatively aseptic water would outweigh the stress due to confinement. We could also check the postoperative progress of each fish. Transmitters were implanted using more sterile surgical techniques. The fish were returned to the same tank and fresh well water was added daily. On days 1 through 3 the fish looked healthy and showed no sign of infection. On the third day, one half of the water was replaced with river water to acclimate the fish to natural conditions. After the river water was pumped into the tank, the suture holes, incisions and abrasions showed signs of reddening and swelling. It is unclear if this was a normal response to surgical stress or was in response to exposure to river water. The fish were released on day 4. We estimate that modifications in surgical procedures reduced mortality from approximately 50% to 25%, although bacterial infection probably still caused the deaths

following surgery.

Based on this information we felt confident we could reduce mortality in the 1988 implants and eliminate the need for holding the fish prior to and after surgery by using more sterile procedures in the field and implanting earlier in the year (March & April) when water temperatures were lower. Rates of tag loss and/or mortality were much lower in 1988. Most of the transmitters were implanted in April and May and only 3 fish were found dead. One of the three had expelled its transmitter.

Thirty-eight fish were implanted in 1987 and 48 were implanted in 1988. Overall, 252 observations were made on 29 fish in 1987 and 729 observations were made on 36 fish in 1988 (Appendix B and C). In 1987 we estimate 39.5% died and 42% expelled their transmitter sometime during the life of the transmitter for a mortality and tag loss rate of 81.5%. Our estimates for 1988 are 6% mortality and 32% expulsion for a mortality and tag loss rate of 38%.

Water Quality

Water temperature (surface) peaked at 90.1 and 90.0^{o}F in July 1987 and August 1988 respectively (Figure 6). Surface and bottom water temperatures rarely differed by more than 1^{o}. Dissolved oxygen levels were generally higher in the summer of 1988 than they were in summer of 1987. Un-ionized ammonia was present at levels of 0.05 to 0.23 ppm. Sheehan and Lewis (1986) determined NH_3-N concentrations $\geq$ 0.74 ppm (from ammonium chloride solutions at 70^{o}F and pH $\geq$ 6.0) were acutely lethal to juvenile channel catfish. Although the levels we

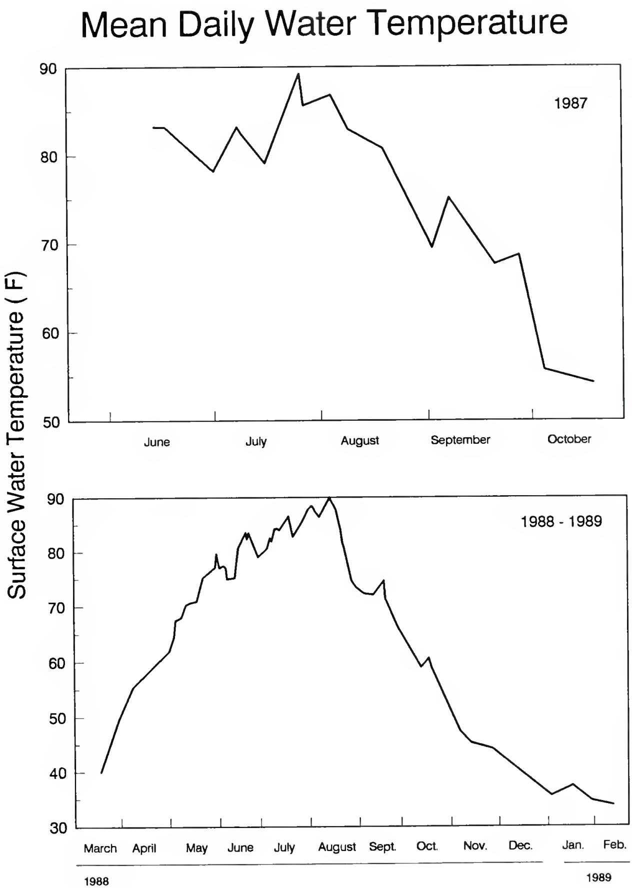


Figure 6. Mean daily water temperatures of the Illinois River at Havana, Illinois.

recorded were not acutely toxic, chronic exposure at these levels may be stressful. Additional water quality data are presented in Appendix D and E.

Habitat Use

<u>Habitat use in relation to lock closure</u>

Pre-Closure, 15 June to 13 July 1987

Prior to lock closure side channel habitat was most preferred and main channel was least preferred (Figure 7). Main channel border was used in greater proportion than it was available and backwater areas were used in lesser proportions than available. This period coincided with the end of the channel catfish spawning season. A portion of the locations in the main channel and main channel border habitats may be due to the fish seeking and utilizing cavities in relation to spawning. Water levels were not high enough to create temporary backwater habitat. Tributary habitat use reflects use of tributaries by fish caught tagged and released in the mainstem, not by those fish caught, tagged and released in Spoon River. We captured, radio tagged, and released 4 channel catfish in the lower mile of Spoon River (Figure 5). All of these fish remained in the tributary and moved up the tributary an average of 5.1 mi. During the pre-closure period, mainstem fish used tributaries approximately in the proportion that they were available.

During Closure, Low Flow, 14 July to 15 August 1987

During the lock closure, low flow, there was a increase in use of main channel habitat but it was still not used in the proportion that

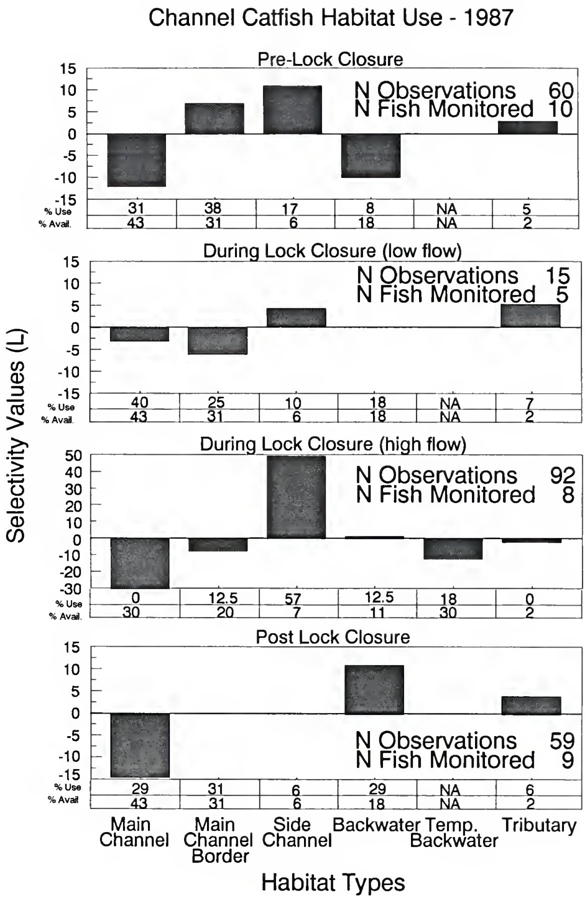


Figure 7. Habitat selection by radio-tagged channel catfish in relation to lock closure.

it was available. All habitat types were used approximately in the proportion that they were available. This period was the time of highest tributary use by mainstem fish. One fish that was radio tagged in the Illinois River 2 mi below the mouth of Quiver Creek moved 0.5 mi up the Creek (Figure 5) for two days and then returned to the Illinois River.

During Closure, High Flow, 16 August to 7 Sept. 1987

The high flows during the closure period (Figure 8) altered the availability of the habitat components. The radio-tagged fish sought the newly flooded vegetation that had grown on the mud flats and shorelines exposed during summer low flows. This accounts for the use of temporary backwater and increased use of side channel and main channel border habitats. The high selectivity values (L) for side channel habitat result from the utilization of a temporarily inundated abandoned channel (side channel without permanent flow). The fish utilizing the main channel during closure, prior to high flow, may have left the main channel to avoid higher velocities or may have been seeking forage on the inundated floodplain.

Post Closure, 8 Sept. to 18 Nov. 1987

As tow traffic resumed the water levels were slightly above normal but the availability estimates for surface elevation of 430.5 ft were more accurate than those for high flow elevation. Backwaters had the highest selectivity value (L) and main channel had the lowest selectivity. Other habitats were used in approximate proportion to there availability.

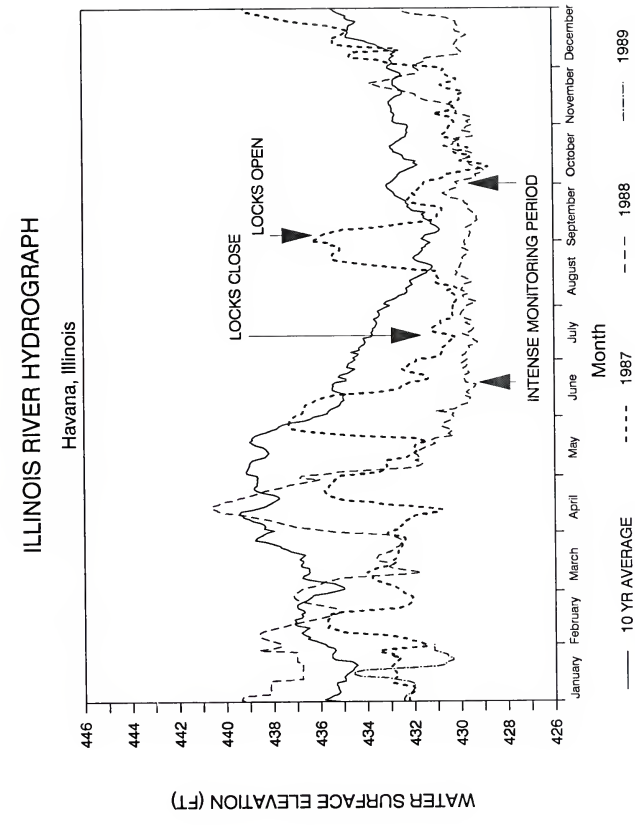


Figure 8. Hydrograph of the Illinois River at Havana, IL

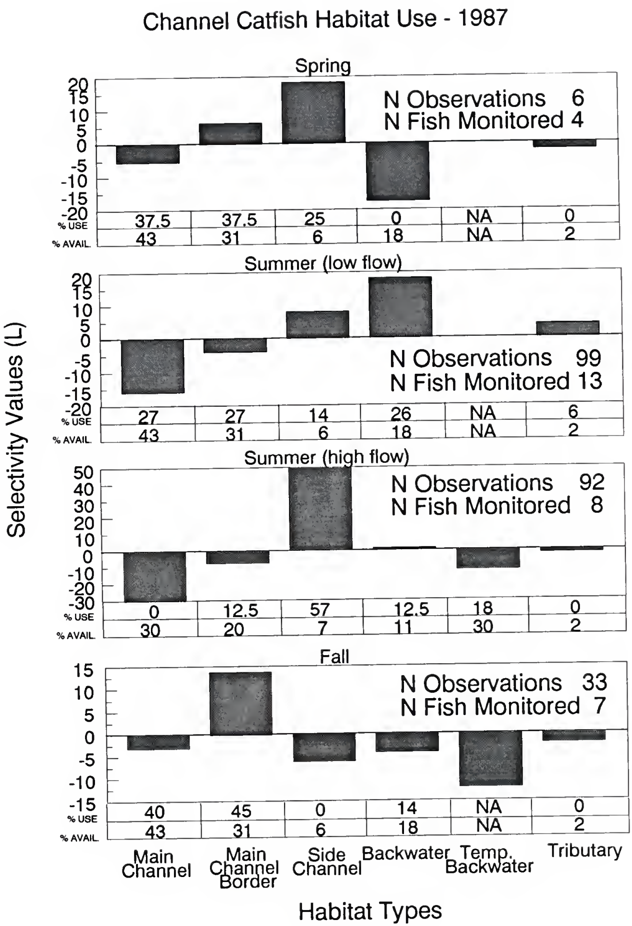
Fluctuating water levels, changing water temperatures and spawning behavior effect habitat selection. For the same reasons a "between seasons" or "between years" statistical analysis of these frequency data would not be valid.

Seasonal Habitat Use

In spring of 1987 a limited number of observations indicated side channel and main channel border habitats were used in greater proportion than they were available (Figure 9). In spring 1988 all habitats except main channel were used in greater proportion than they were available (Figure 10). Selectivity values (L) for main channel were -6 in 1987 and -25 in 1988.

In the summer of 1987, under low flow conditions, side channel and backwaters had the highest selectivity values (L). In summer 1988, side channel, main channel border and tributary habitats had positive electivity values (L) and main channel and backwaters had negative values. In 1988 water levels were not sufficient to create temporary backwater habitats as seen in 1987, in addition, the backwater habitat was extremely shallow (average depth < 3 ft). This may explain the negative selectivity (L) for backwaters in 1988. Habitat use during the high water levels in the summer of 1987 has been previously discussed in the Habitat Use in Relation to Lock Closure section.

Four channel catfish were radio-tagged and released in Spoon River in the summer of 1987. These four fish remained in the tributary. In 1987, no radio-tagged fish from the Illinois River moved into Spoon River but one did move into Quiver Creek temporarily.



Season		Main Channel	Main Channel Border	Side Channel	Backwater	Temp. Backwater	Tributary
Spring	% USE	37.5	37.5	25	0	NA	0
	% AVAIL.	43	31	6	18	NA	2
Summer (low flow)	% USE	27	27	14	26	NA	6
	% AVAIL.	43	31	6	18	NA	2
Summer (high flow)	% USE	0	12.5	57	12.5	18	0
	% AVAIL.	30	20	7	11	30	2
Fall	% USE	40	45	0	14	NA	0
	% AVAIL.	43	31	6	18	NA	2

Figure 9. Seasonal habitat selection by radio-tagged channel catfish in 1987.

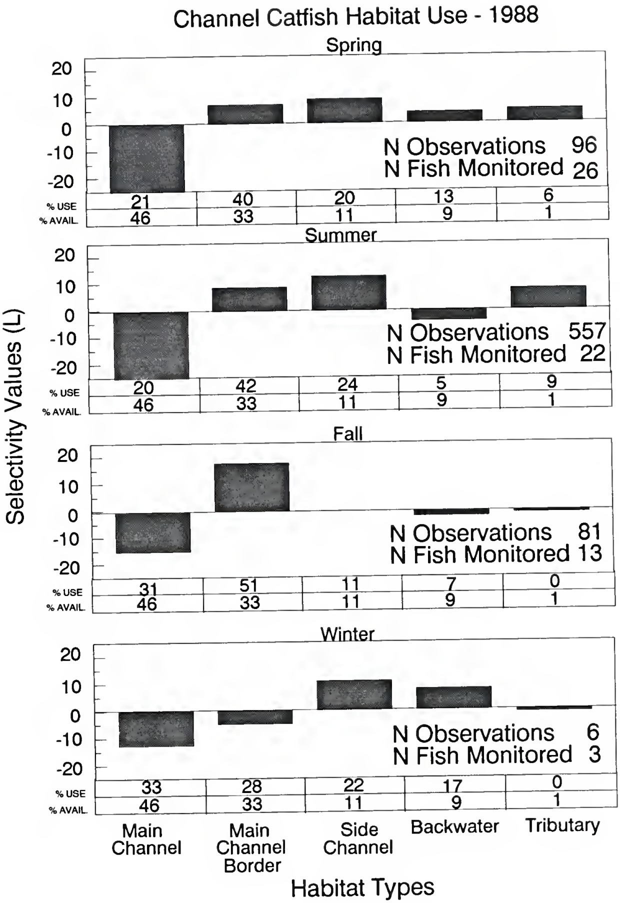


Figure 10. Seasonal habitat selection by radio-tagged channel catfish in 1988.

In 1988, no fish were radio-tagged and released in Spoon River, however, two fish did move into the tributary and stayed in the tributary until they expelled their transmitters in late summer.

During the fall of 1987 and 1988, main channel border and main channel accounted for 85 and 82% of the locations, respectively. Main channel border had the highest selectivity values (L) of any habitat in the fall. Main channel had negative selectivity values (L) but they were some of the highest values recorded for main channel in any season. Behavioral shifts to deeper areas in response to the cooler water temperatures in fall (Figure 6) may explain the high selectivity values (L) recorded for main channel and main channel border.

Radio-tagged channel catfish were not observed in the winter of 1987 (16 December 1987-28 February 1988). A limited number of observations in the winter of 1988 indicated side channel and backwater areas were used in greater proportion than they were available. A rise in water levels may explain the higher use of side channel and backwater habitats and consequently the lower use of main channel than in the fall of 1987 and 1988. If the water levels would have remained stable, we would expect higher selectivity values (L) from the deeper main channel and main channel border habitats.

Statistical Analysis of Habitat Use vs. Availability

The difference in selection of navigable and non-navigable channel was not significant ($P = 0.11$) for the subset of fish that was intensively monitored in the summer of 1988. The mean selectivity values (L) were positive for non-navigable channel and negative for navigable channel (Table 1). There was no significant difference in

Table 1. Habitat availability and selection (L values) for eight radio-tagged channel catfish during summer.

	Habitat Availability and Selection										
	Navigable Channel					Non-Navigable Channel			Non-Channel		
Depth (ft)	Proportion[1] Available	Main Channel (L)		Main Channel Border (L)		Proportion Available	Side Channel (L)		Proportion Available	Backwater (L)	
		Day	Night	Day	Night		Day	Night		Day	Night
0.0- 1.6	0.08	na	na	-0.07	-0.06	0.13	-0.12	-0.12	0.05	-0.04	-0.03
1.7- 3.3	0.05	na	na	-0.02	-0.02	0.03	+0.02	+0.03	<0.01	not used	
3.4- 4.9	0.07	na	na	+0.05	+0.04	0.03	+0.02	+0.01	<0.01	not used	
5.0- 6.6	0.04	na	na	+0.07	+0.07	0.05	+0.11	+0.13	<0.01	not used	
6.7- 8.2	0.05	na	na	-0.02	-0.02	0.02	+0.03	+0.05	na		
8.3- 9.8	0.07	na	na	-0.05	-0.05	0.03	+0.01	-0.01	na		
9.9-11.5	0.06	+0.02	+0.02	na	na	0.03	+0.03	-0.02	na		
11.6-13.1	0.09	-0.02	-0.04	na	na	<0.01	+0.04	+0.04	na		
13.2-14.8	0.13	-0.12	-0.11	na	na	na			na		
Total	0.64	-0.12	-0.13	-0.04	-0.04	0.32	+0.14	+0.11	0.05	-0.04	-0.03

1 - Proportions sum to 1.01 (0.64+0.32+0.05=1.01) instead of 1.00 because of rounding errors.
na = depth category not available in the habitat category, so L values could not be calculated.

selection of day and nighttime habitats (P = 1.0). As previously stated, main channel border and main channel were combined into navigable channel to make depth independent of habitat thus allowing navigable channel to be compared to side channel. Depths from 3.4 to 8.2 ft had higher selectivity values (L), often positive, in all habitat types except backwater where these depths were available in very limited proportions (e.g. <0.01; Table 1).

Movement

Long-Term Movement Patterns

Movement data was collected on 24 and 33 fish in 1987 and 1988 respectively (Table 2). A mean gross movement of 3.9 mi was recorded in 1987. Two fish exhibited net upstream movement averaging 1.5 mi, 10 fish had no net movement and 8 fish had a net downstream movement averaging 6.6 mi. Four fish moved up Spoon River, a major tributary in the study area, an average of 5.1 mi. These fish were released in the tributary near the mouth and remained in the tributary for all of 1987. One fish released in the Illinois River moved up Quiver Creek 0.75 mi but returned to the Illinois River two days later.

Mean gross movement in 1988 was 3.3 mi (Table 2). Six fish had a net upstream movement averaging 1.9 mi, 12 fish had no net movement and 13 fish moved downstream an average of 3.4 mi. Two fish moved up Spoon River an average of 2.4 mi. These fish were from a site in the Illinois River 0.75 mi upstream of the tributary mouth.

Table 2. Summary of of radio-tagged channel catfish movements in 1987 and 1988.

Year	# of Fish	Gross Movement Mean (miles)	Net Movement (miles)					
			Upstream		No Movement		Downstream	
			#	(mean)	#	(mean)	#	(mean)
1987	24[1]	3.9	2	1.5	10	-	8	6.6
1988	33[2]	3.3	6	1.9	12	-	13	3.4

[1] Four of these fish moved up Spoon River an average of 5.1 miles

[2] Two of these fish moved up Spoon River an average of 2.4 miles

Note: movements in Spoon River are not reported in this table.

Radio-tagged fish were sedentary most of the time. In 1987, 83% of movements were $\leq$0.11 mi, in 1988 the figure rose to 91.5%. Some fish did exhibit sporadic long distance movements. In 1987 and 1988 respectively, 5.3% and 2.7% of the movements were > 1.0 mi. Movements of individual radio-tagged fish are presented in Appendix F and G.

Seasonal Movement Patterns

Mean distance moved/day peaked in late spring/early summer in 1987 and 1988 (Figures 11 and 12). The increased long range movements seen in 1987 occurred in conjunction with water level fluctuations as well as a late summer flood. Movements in 1988 increased in late fall for a short period. Fish generally exhibited more movement in summer 1987 than in 1988. We feel this probably can be attributed to the extremely low stable water levels present in 1988.

In 1987 mean gross movements peaked at 5.1 mi and mean net movements were downstream and peaked at -3.0 mi during summer (Table 3). Mean gross movements in 1988 were similar for spring (1.9 mi), summer (2.0 mi) and fall (1.3 mi). Gross movements during winter increased to 3.5 mi. This increase in winter is probably due to fluctuating water levels. Mean net movements were downstream in the spring (-1.2 mi) and summer (-0.6 mi) and upstream during fall (0.4 mi). Winter net movements were downstream (-3.3 mi).

Fish were most sedentary during the fall of 1987 and summer of 1988 with 96.7% and 95.5% of movements $\leq$0.11 mi, respectively (Table 3). Long range movements (>1.0 mi) were most frequent during summer

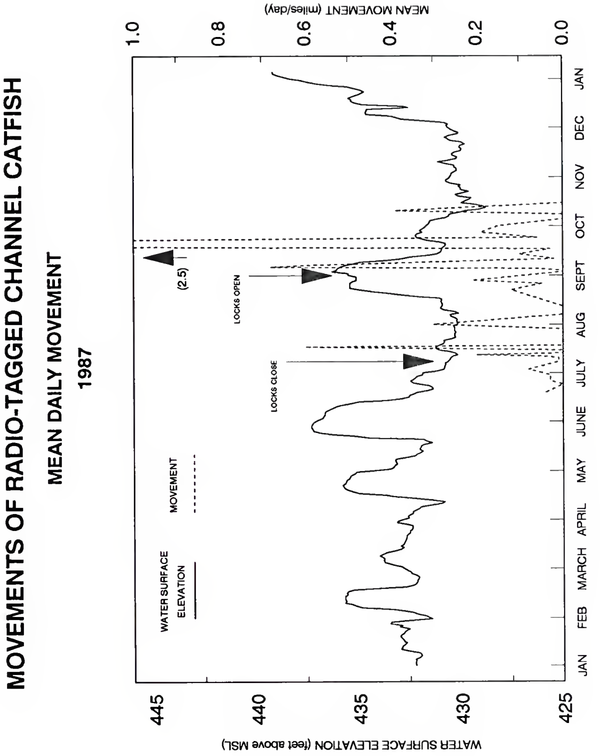


Figure 11. Movements of radio-tagged channel catfish in 1987.

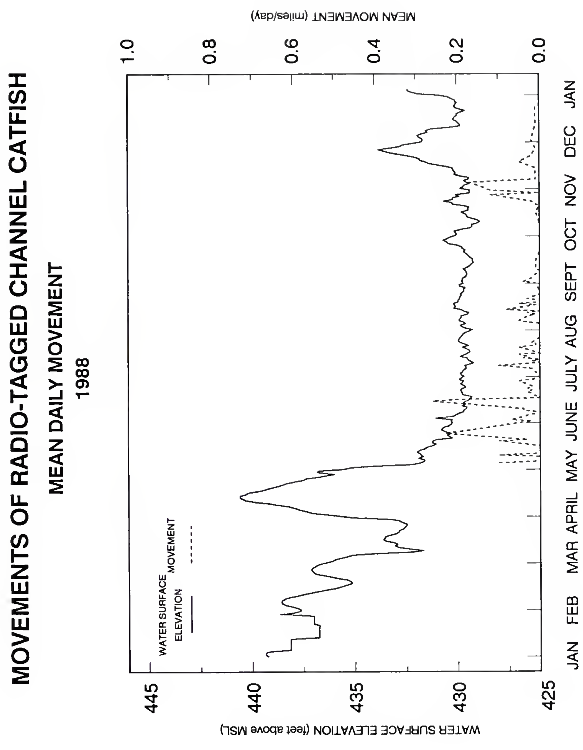


Figure 12. Movements of radio-tagged channel catfish in 1988.

Table 3. Summary of seasonal movements of radio-tagged channel catfish in 1987 and 1988.

Season	Frequency (%)			Gross Movement (mi)			Net Movement[1] (mi)		
	< 0.11 mi	0.11 to 1.0 mi	> 1.0 mi	Mean	Min.	Max.	Mean	Min.	Max.
1987									
Spring	50.0	50.0	0.0	0.1	0.0	0.2	-0.1	0.0	-0.2
Summer	81.3	13.1	5.6	5.1	0.0	27.6	-3.0	0.0	-27.4
Fall	96.7	0.0	0.3	1.0	0.0	7.0	-1.0	0.0	-7.0
Winter	----	---	---	---	---	---	---	---	---
1988									
Spring	72.3	18.5	9.2	1.9	0.0	14.1	-1.2	0.0	3.0
Summer	95.5	3.4	0.1	2.0	0.0	13.0	-0.6	0.0	-6.6
Fall	85.3	9.3	5.4	1.3	0.0	8.3	0.4	0.0	5.5
Winter	33.3	33.3	33.3	3.5	2.9	4.0	-3.3	-2.9	-3.7

[1] Plus or minus indicates whether last location was upstream or downstream of initial location, + = upstream.

of 1987 (5.6%) and during spring (9.2%) and fall (5.4%) of 1988.

Diel Movement

In 1987 diel movement peaked at 700 ft/4 hr from 1600-2000 hours (Figure 13). A well defined peak in activity was not observed in 1988. Maximum and minimum movements were 210 ft/4 hr from 2000-2400 hours and 25 ft/4 hr from 1200-1600 hours, respectively.

Movements in Relation to Lock Closure

Pre-Closure, 15 June to 13 July 1987

Radio-tagged fish exhibited a gross movement of 1.6 mi and a net downstream movement of 1.3 mi during the pre-closure period (Table 4). Most movements recorded (76.1%) were $\leq$0.11 mi, with only 2.2% >1.0 mi.

During Closure, 14 July to 7 Sept. 1987

During the period of lock closure the mean gross movement rose to 2.4 mi. The net movement was still downstream 0.3 mi. The frequency of movements $\leq$0.11 mi increased slightly to 79.3%. Movements >1.0 mi increased to 6.9%.

Post-Closure, 8 Sept. to 18 Nov. 1987

Gross movements increased to 5.4 mi and net movement was downstream 4.4 mi following reopening of the locks (Table 4). The frequency of short range movements remained stable, however, long range movements increased to 8.5%.

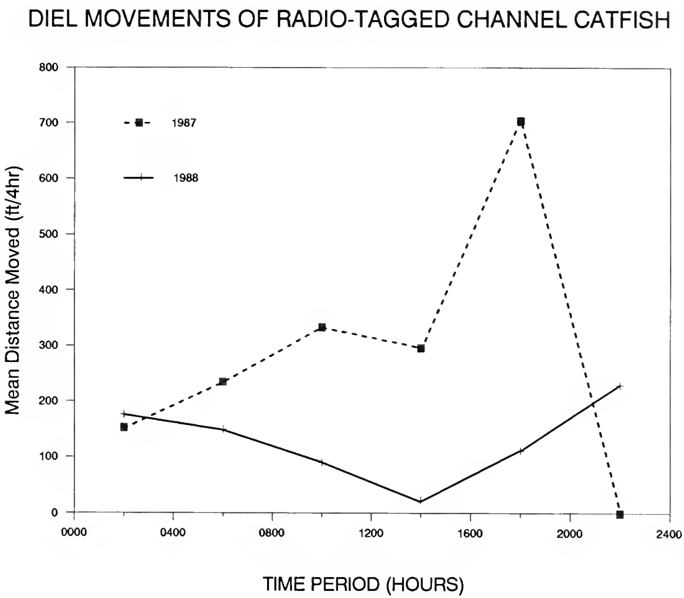


Figure 13. Diel movements of radio-tagged channel catfish.

Table 4. Frequency, distance and direction of channel catfish movements in relation to lock closure.

Time Period	Frequency (%)			Gross Movement			Net Movement[1]		
	< 0.11 mi	0.11 to 1.0 mi	> 1.0 mi	Mean	Min.	Max.	Mean	Min.	Max.
Pre-lock closure	76.1	21.7	2.2	1.6	0.0	7.2	-1.3	0.0	-7.2
During lock closure	79.3	13.8	6.9	2.4	0.0	9.3	-0.3	0.0	-4.5
Post lock closure	80.9	10.6	8.5	5.4	0.0	27.5	-4.4	0.0	-27.5

[1] Plus or minus indicates whether last location was upstream or downstream of initial location, + = upstream.

Movement in Response to Tow Passage

In relation to lock closure

Navigation traffic levels before and after the 56-day closure period reached conservative levels predicted to occur in the 21st century (Figure 14). The frequency of tows followed the pattern predicted but the pre-closure peak was in May and early June. We did not have any fish radio tagged in May and we only had a few radio tagged in early June. The traffic peak after the locks reopened was in November and December when tracking conditions were unsafe and a limited number of transmitters were still broadcasting.

The design of the Peoria and La Grange locks are an exception to most of the locks in the Upper Mississippi River system. These locks use collapsible wickets to control pool levels. A situation called open pass can be created when water levels are high and the wickets are laid down. In this situation tows pass over the dam instead of through the lock.

The flood that occurred in August and persisted through the middle of September (Figure 8) allowed the resumption of tow traffic (open pass) for a week prior to the formal reopening of the locks.

None of the radio-tagged fish were located in the main channel immediately before or after the locks reopened and only two fish selected the main channel border (the remaining fish were utilizing backwaters, temporary backwaters and side channels apparently in response to the high water levels). These two fish were monitored

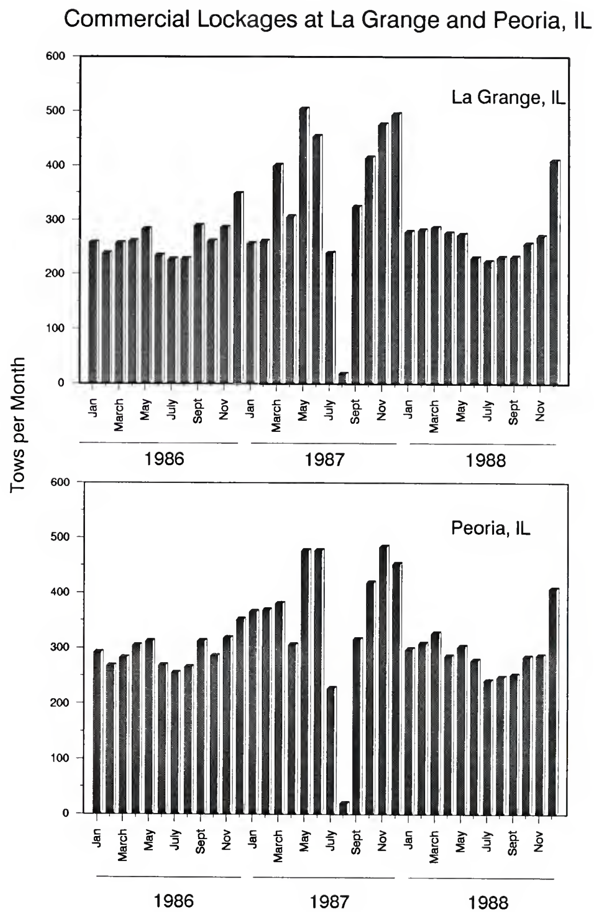


Figure 14. Commercial lockages at Illinois River locks at La Grange and Peoria, IL.

intensively as the first tows passed when the locks reopened.

One of these fish occupied a sunken barge where it was probably protected from propeller and wave wash. This fish was approximately 75 ft from the edge of the main channel. The other fish was 250 ft from the edge of the main channel. The two fish were monitored during 11 tow passages.

We defined a response as detectable movement, usually movements greater than 15 ft. Occasionally we could tell if a fish was moving shorter distances by the changing signal strength. We did not want the presence of our tracking boat to influence the fish's behavior so we made these location estimates by triangulation.

Responses were observed during passage of; 1 of 3 downstream tows, 5 of 8 upstream tows, 1 of 2 empty tows, 3 of 4 fully loaded tows, and 2 of 5 partially loaded tows. Overall, responses were observed during 6 of 11 tow passages. The mean distance moved for these six observations was 73 ft. We did not detect responses to tows passing over 230 ft from the fish. There was no clear trend to indicate movement to deeper or shallower water or to cover.

Response to tow passage throughout the study

Radio-tagged fish were monitored as individual tows passed throughout the study. Several trends are suggested by the results in Table 5. Radio-tagged channel catfish > 131 ft from the tow responded more often than those $\leq$ 131 ft. Fish in the main channel

Table 5. Radio-tagged channel catfish movement in relation to tow passage throughout the study.

QUESTION	Yes	No	Movement (ft) Mean	Min	Max
Did fish respond to tow passage	12	11	80	0	197
Did fish ≤ 131 ft from tow respond	4	5	60	16	197
Did fish > 131 ft from tow respond	8	4	90	49	197
Did fish respond to upbound tow[1]	6	5	103	16	197
Upbound, full	5	4	110	16	197
Upbound, empty	1	1	66	-	-
Did fish respond to downbound tow[1]					
Downbound, full	3	1	79	49	131
Downbound, empty	no passages observed in this category				
Did fish respond to number of units in tow					
Number of units					
1-5	3	2	46	16	66
6-10	2	5	87	59	115
11-15	7	2	108	26	197

[1] partially loaded tows not included

border may be disturbed by the drawdown effect created by passing tows. Fish $\leq$ 131 ft from the tow were mostly located in or near the main channel. These fish were often associated with cavities, or structures such as sunken barges or logs. Fish moved in response to 52% of the tow passages (Table 5) and there seems to be a relation between the distance moved and the number of units in a tow. For further information see Appendix H.

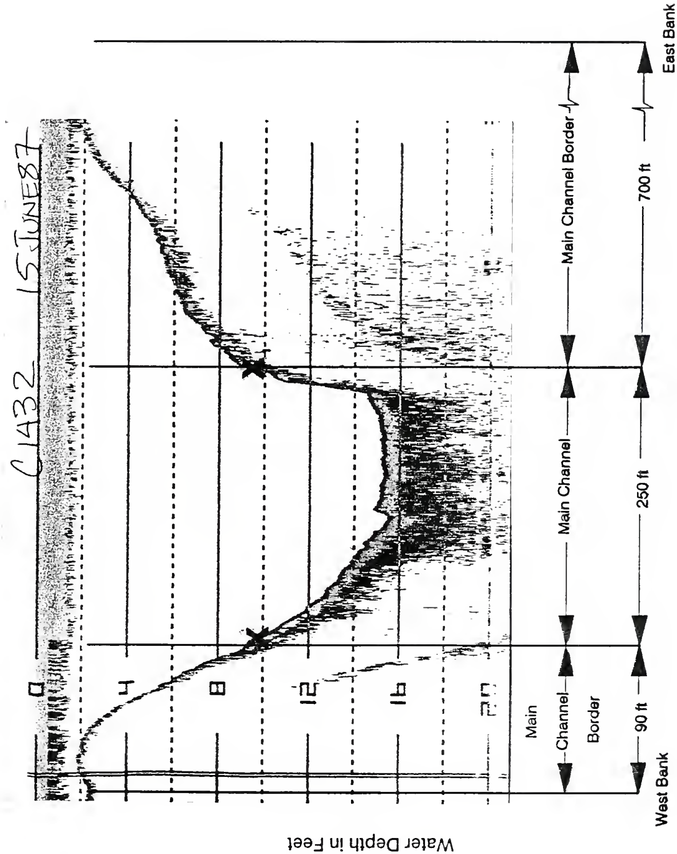
We want to point out that in all of our observations (routine, intensive, and in relation to passage of individual tows) the radio-tagged fish were never located near the center of the 300-ft-wide main channel. Rather, they were usually at the bottom of the steep decline defining the edge of the main channel border and main channel (Figures 15 and 16).

Depth Selection

Mean depths selected in spring 1987 and 1988 were similar, 7.2 and 6.6 ft respectively (Figure 17). The range of depths selected was slightly wider in 1988.

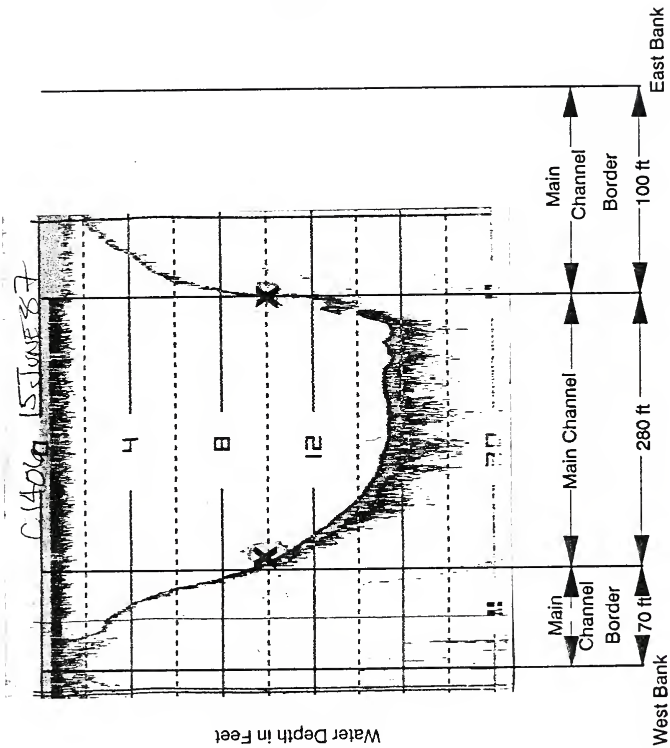
The mean depth selected in summer 1987 was 1.9 ft less than it was in the spring and 1.7 ft less than in the summer of 1988. There was a slight increase (0.4 ft) in mean depth selected from spring to summer in 1988.

Average depth selected in the fall of both years was deeper than in previous seasons. Depths for both years are similar (8.2 ft in 1987 and 8.7 in 1988). A wider range of depths were selected in 1988.



X - Designates usual location of fish when occupying the main channel.

Figure 15. Cross section of the Illinois River at river mile 121.0.



X - Designates usual location of fish when occupying the main channel.

Figure 16. Cross section of the Illinois River at river mile 120.6.

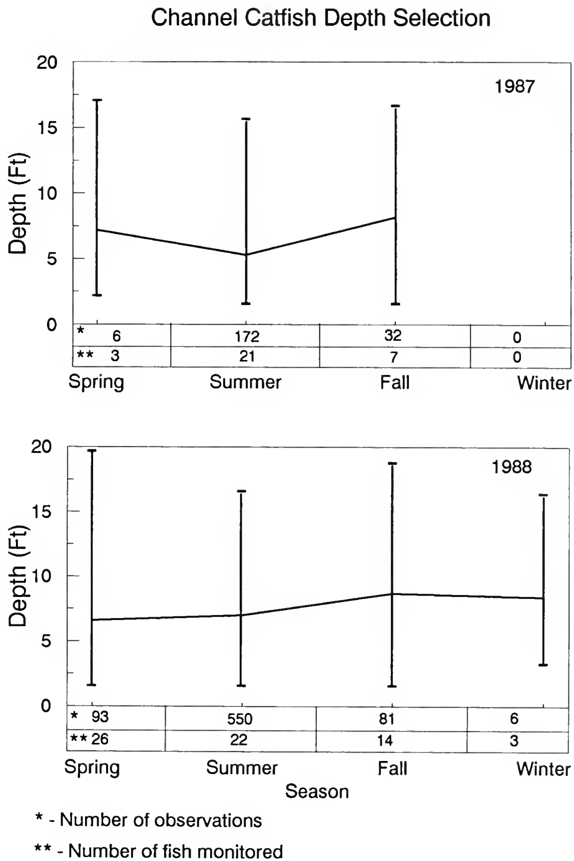


Figure 17. Depth selection by radio-tagged channel catfish.

A limited number of observations were made in the winter of 1988 and no observations were made in the winter of 1987. Mean depth selected in winter 1988 was similar to the mean depth selected in the fall 1988, 8.4 and 8.7 ft respectively. The narrow range of depths selected in winter is probably a result of the limited number of observations.

Velocity Selection

Velocities selected in different seasons varied significantly. Higher velocities were selected in fall-winter and spring than were selected in summer ($P < 0.05$; Table 6). Velocities selected during day and night were not significantly different ($P = 0.77$).

The difference between seasons is statistically significant, but it is probably not biologically significant. Mean velocities selected in all seasons are within or near the range classified as most suitable (0.0-0.49 ft/s) for channel catfish in cover areas during average summer flow (McMahon and Terrell 1982).

Table 6. Mean current velocities (ft/s) selected by radio-tagged adult channel catfish.

Season	Period	N Obs	Mean	Minimum	Maximum
Fall-Winter	Day	26	0.56	0.00	1.48
Spring	Day	36	0.56	0.00	1.15
	Night	3	0.92	0.89	0.98
	Combined	39	0.59	0.00	1.15
Summer	Day	85	0.39	0.00	1.02
	Night	49	0.43	0.00	1.02
	Combined	134	0.39	0.00	1.02

DISCUSSION

Few investigators have reported on the habitat use and movement of channel catfish in navigable rivers using data collected from radio-tagged fish. To our knowledge, no other investigators have looked at adult channel catfish behavior in response to tow traffic.

Dames (1988) and Grace (1985) used radio telemetry to monitor channel catfish in the Missouri River and Stang and Nickum (1985) and Pellett and Fago (1985) have monitored channel catfish in the Upper Mississippi River. Dames' work was primarily focused on use of tributaries and Graces' work centered on winter movement and habitat use. Pellett and Fago's telemetry objectives were to document seasonal movement. Stang and Nickum had objectives similar to ours but our observations were more frequent and our habitat use analysis includes a use vs. availability analysis. Other studies regarding channel catfish habitat use in navigable rivers are based on underwater observations (Hawkinson and Grunwald 1979; Lubinski 1984) or hoop-net catches (Ragland 1973; Ellis et al. 1979; Hubert 1981). Many channel catfish movement studies based on mark and recapture data have been conducted in large rivers (e.g. McCammon 1956; Hubley 1963; Hesse et al. 1982; Pellett and Fago 1985; Hale et al. 1986; Dames 1988).

Several expert panels (e.g. Harber et al. 1981; Kennedy et al. 1981) discussed the potential direct impact by tows on the different life stages of channel catfish and concluded juveniles were probably at greatest risk since they frequently inhabit the main channel.

Spawning adults and larvae may also be disturbed by the currents and shear forces tows create. There have been several studies that document habitat utilization by adult channel catfish in relation to potential navigation related impacts. Hawkinson and Grunwald (1979), Lubinski (1984), and Stang and Nickum (1985) documented channel catfish overwintering in deep areas of the main channel and main channel border. These authors all concluded that dredge spoil should not be deposited in thalweg areas with extensive cover. They also concluded that winter navigation would make these areas unsuitable for overwintering.

Mortality soon after surgical implantation of the transmitter was a major problem in the initial 1987 tag set. Mortality coupled with transmitter expulsion in the fish that did survive accounts for the small number of fish monitored and low number of observations/fish. Adoption of more sterile surgical techniques later in 1987 may have helped increase survival from ~50% to ~75%. The transmitters were implanted one to two months earlier in 1988 and mortality was much lower (6%). The lower water temperatures at the time of implantation and the consistently higher, more stable dissolved oxygen levels throughout the spring probably accounted for most of the increase in survival. Transmitter expulsion, estimated at 42% in 1987 and 32% in 1988, was still a problem. Summerfelt and Mosier (1984) reported a 71% expulsion rate.

Several physical-chemical factors probably were stressful to fish in the Illinois River during the study period. We determined un-ionized ammonia was present at levels of 0.05 to 0.23 ppm at pH

ranging from 8.3 to 8.9 in 1988. These concentrations are not lethal to juvenile channel catfish in acute tests (Sheehan and Lewis 1986) but may be sufficient to stress channel catfish. Concentrations >0.05 ppm resulted in slower egg to swim-up fry development times and concentrations $\geq$ 0.33 ppm reduced channel catfish larvae growth rates (Reinbold and Pescitelli 1982b). Roseboom and Richey (1977) and Reinbold and Pescitelli (1982a) determined acute toxicity of un-ionized ammonia, to channel catfish fry (<0.5 oz).

Investigator	Un-ionized ammonia LC50 (ppm)	Temperature (^{o}F)	pH
Roseboom and Richey (1977)	1.5	72	7.77-8.41
Roseboom and Richey (1977)	3.0	82	7.91-8.25
Reinbold and Pescitelli (1982a)	1.45	75	7.75-8.12

High ammonia levels can contribute to *A. hydrophila* infections (Cipriano et al. 1984). Levels of dissolved oxygen fluctuated throughout the study (range 1.1 to 18 ppm) and levels were often low enough to be considered stressful (e.g. 1.1, 2.0, 3.4 ppm).

Fish usage of the main channel did increase during the low flow period during lock closure. However, the main channel still was not a preferred habitat (utilized in the proportion it was available). We feel changes in habitat use were also associated with seasonal changes in behavior and water level fluctuations as well as differences in traffic levels.

The period before lock closure coincided with the channel catfish

spawning period (late spring). Channel catfish frequently spawn in cavities (Marzolf 1957; Deacon 1961; Pflieger 1975). It is possible that there are more exposed roots along the main channel border than in side channels because of wave wash caused by boats. If late spring water levels are high enough -- channel catfish may be attracted to cavities among the roots. If drawdowns and wave wash reduce hatching success and fry survival, the net effect is negative: i.e. channel catfish are induced to spawn in areas where hatching success will be low. In the main channel steep clay banks with crevices and cavities probably provide suitable spawning sites but, in light of the currents created by passing barges the hatching success of these nests may not be high. On one occasion (July 11, 1988) we located one of our radio-tagged channel catfish in a cavity along the main channel border. In the course of exploring the cavity, we came into contact with the fish and caused it to flee.

The flood that began one week prior to the locks reopening created an abundance of temporary backwaters. The channel catfish moved into the inundated vegetation characteristic of temporary backwaters as soon as the areas were flooded to a 0.5-to-1-ft depth. Guillory (1979) also found channel catfish moved into floodplain habitats as they were inundated. This shift in habitat generally put the fish far from main channel and main channel border habitats as the locks reopened.

The use of the main channel after the locks reopened (late summer and fall) is probably due to decreasing water temperatures. Other investigators have reported that channel catfish select deeper water

as water temperature declines in the fall (Stang and Nickum 1985; Dames 1988). This shift to deeper habitats was also documented in the fall of 1988.

The frequency of each category of movement did not vary greatly in relation to lock status and barge traffic. Movement increased as the water levels fluctuated in late summer. The increase in the movements > 1.0 mile category is due to several fish making long downstream movements (up to 27 mi) as water levels receded.

Only fish in the main channel and main channel border responded to tow passage. As the locks reopened no fish were located in the main channel and only two fish were in the main channel border. These two fish moved during 6 of 11 tow passages. The mean distance moved for these six observations was 73 ft. Throughout the study, individual fish exhibited movement during 12 of 21 tow passages. When a fish responded it moved an average of 87 ft/passage. One reason the average movement/passage is greater for the entire study rather than immediately after lock opening may be that one of the two fish occupied a sunken barge where it was probably protected from propeller and wave wash.

There was no clear trend to indicate movement to deeper or shallower water or to cover as tows passed. Radio-tagged channel catfish > 131 ft from from the tow responded more often than those $\leq$ 131 ft. This may be a result of disturbance of the fish located in the shallower main channel border by the drawdown created by passing tows. Fish $\leq$ 131 ft from the tow were mostly located in or near the

main channel. These fish were often associated with cavities, a sunken barge, or logs--possibly seeking protection from propeller and wave wash. Although the frequency of disturbance does not appear to be related to the number of units in a tow, when a response was observed there seemed to be a relationship between distance moved and the number of units in a tow (1-5 units/tow, 6-10 units/tow, and 11-15 units/tow caused an average movement of 46 ft, 87 ft, and 108 ft respectively). Downbound tows were more likely to cause a response (response 75% of the time) than were upbound tows (response 54% of the time). Holland (1986) found upbound empty tows to have more of an impact on freshwater drum eggs than downbound loaded tows, but immediate mortality of larval fish was not significant. Shear-related mortality of larval paddle fish has been documented (Killgore et al. 1987). Bhowmik et al. (1981a) report that drawdown is affected by vessel velocity, vessel length, distance to the sailing line and draft.

Passage of individual tows did not influence the habitat selection or movement of channel catfish to the extent we had hypothesized, however, during the course of the study we observed individuals of several species of fish that had been damaged by passing tows. Two channel catfish and two flathead catfish were found floating in the main channel with portions of their bodies either partially or completely severed. In the most vivid case, a 24-lbs portion of a flathead catfish was found floating in the main channel 500 ft behind an upbound tow. This fish was completely severed immediately behind the dorsal fin but was still trying to swim. More

frequently observed were partially or completely severed buffalo (*Ictiobus* sp.). We observed at least 20 individuals still alive and upwards of 100 dead severed fish. The dead severed fish cannot positively be attributed to contact with tow boat propellers because they might have died from other causes and then been drawn into the propellers. Gizzard shad (*Dorosoma cepedianum*) were frequent victims but the number of individuals observed in the fall was much greater than in other seasons. When water temperatures declined to approximately 50^0, passing tows would be observed churning up hundreds of live young-of-year (3 to 4 inches total length) gizzard shad. These individuals would rarely be severed but they would have bloody eyes and mouths which, in our opinion was the result of the extreme shear forces generated by the propellers. These fish usually had mud under their scales and gill covers on one side of their body. Herring gulls and ring-billed gulls were quick to take advantage of this phenomenon. Flocks as large as 200 birds were observed following the tows and feeding on the stunned gizzard shad.

Utilization of habitats and depth changed with the seasons. In spring and summer side channel, main channel border, and tributary habitats were generally more preferred than backwaters and main channel. Side channel was always the most preferred habitat. Spring depth selection averaged approximately 7 ft in both years. From spring to summer 1987 average depth selected decreased 1.9 ft as a result of fish utilizing the shallow temporary backwaters created by the late summer flood. Average depth selected in summer of 1988 was

slightly deeper than in spring. In fall the main channel border was utilized more than in any other season and had the highest selectivity value (L) of any habitat. In 1987 and 1988 average depth selected in the fall was deeper than it was for either summer. In winter, side channel and backwaters had the highest selectivity values (L) but more stable water levels may have resulted in higher selectivity values for the deeper main channel and main channel border habitats. The average depth selected decreased slightly in winter.

The change from use of shallow areas such as backwaters and shallow portions of main channel border and side channels in spring and summer to main channel and deeper portions of main channel border and side channels in fall and winter has been documented (Stang and Nickum 1985). In our study the average depth selected in spring and summer is 0.9 ft less than was reported by Stang and Nickum and is within the range reported for channel catfish in smaller streams (Dames 1988). Fall and winter average depth selection was 5.5 ft less than what was reported by Stang and Nickum but within the range listed by Dames. The difference in the relative abundance of deep areas in this study compared to the study conducted on the upper Mississippi River by Stang and Nickum probably accounts for the difference in fall and winter depth selection. Larimore and Garrels (1982) reported winter average depth selection of 2.5 ft in a small stream.

Hawkinson and Grunwald (1979) and Lubinski (1984) found the over-wintering sites were always in or adjacent to the main channel on the outside of a bend. We also found that whenever we located a fish in the main channel or main channel border in fall and winter it was

always on the outside of a bend. The greater depth, possible increased bed irregularities due to natural scouring, and greater debris accumulation in these areas may explain the attraction for channel catfish. We did, however, locate some of our channel catfish in backwaters and side channels in fall and winter. Another telemetry study conducted on wintering channel catfish found that the fish selected deep scour holes at the mouths of tributaries (Grace 1985).

Depth and habitat utilization information is valuable but becomes much more meaningful when it is compared to the availability of each component. In the preceding discussion concerning habitat utilization, main channel border, side channel and main channel were the most used habitats in all seasons. However, main channel and main channel border habitats make up ~80% of the available habitat. When the use was compared to availability, side channels were regularly used in greater proportion than they were available. This indicates side channels were being selected over the main channel. Main channel border selectivity varied from positive to negative with the seasons. Overall main channel border was used approximately in the proportion it was available. Stang and Nickum (1985) also alluded to this point in their discussion of the use of off-channel areas in proportion to the availability of the habitats.

In the analysis of the intensive monitoring data we again found that non-navigable channel (side channel) was preferred over navigable channel although the difference in electivity was not significant ($P = 0.11$). Ragland (1973), using hoop nets, reported channel catfish were

caught more frequently in side channels than in the main channel border. Conversely, Hubert (1981) reported hoop net catch rates for channel catfish were higher in the main channel border than they were in adjacent side channels with similar environmental variables. One likely reason why our conclusions do not concur with Hubert's is that the main channel on the Illinois River makes up a larger portion of the main stem than it does on the Mississippi River; thus a fish in the main channel border is generally in closer proximity to passing tows on the Illinois River (Figures 15 and 16). Successional stage of individual side channels is thought to dictate fish community structure in side channels (Ellis et al. 1979). He reported a riverine side channel with high velocities and little sedimentation yielded higher hoop net catch rates of channel catfish than did a lacustrine side channel.

In a stream with riffle-pool development, young-of-year channel catfish made diel shifts in habitat and depth (Deacon 1961). He reported they were ten times more abundant in shallow riffles at night than during daytime. He went on to speculate that adults probably exhibit the same pattern of habitat selection. We determined that the selection of habitats did not differ between night and day ($P = 1.0$). Diel changes in depth selection were not noted either. Depths from 3.4 to 8.2 ft had higher electivity values, often positive, in all habitat types except backwater where the maximum depth was 6.6 ft. We feel large channel catfish may be more sedentary and more of an ambush predator like flathead catfish (Becker 1983).

Higher velocities were selected in fall-winter and spring than in

summer (P < 0.05). Although the difference between seasons is statistically significant, they may not be biologically significant. Velocities selected during day and night were not significantly different (P = 0.77). Stang and Nickum (1985) reported average bottom velocities at channel catfish locations were 0.49 ft/s and 0.89 ft/s in spring-summer and fall-winter, respectively, which were comparable to our values of 0.48 ft/s and 0.56 ft/s. However, the maximum velocities we documented were generally twice as high as theirs. Mean velocities selected in all seasons are within or near the range classified as most suitable for channel catfish (0.0-0.49 ft/s) in cover areas during average summer flow (McMahon and Terrell 1982). Other velocities reported in winter were 0.0-0.9 ft/s (Hawkinson and Grunwald 1979) and 0.21 ft/s (Larimore and Garrels 1982).

Our results from diel monitoring showed peak activity from 1600-2000 hours in 1987 and 2000-2400 hours in 1988. Ziebell (1973) and Dames (1988) recorded peak activity from 2100-0100 hours and Bailey and Harrison (1945) found that channel catfish feed most actively from sundown to midnight. Radio-tagged fish were more active in terms of distance moved/4 hr in 1987. This is probably due to changing water levels throughout most of the diel monitoring period in 1987. Flathead catfish are most active at night (Robinson 1977; Dames 1988).

Channel catfish in rivers occasionally make movements in excess of 200 mi (Hubley 1963) but often 24 to 57% of tagged individuals are recaptured within 2 miles of where they were initially captured (Funk 1955; McCammon and LaFaunce 1961; Hubley 1963; Welker 1967; Hesse et

al. 1982; Hale et al. 1986) and in one study site 95% of the individuals showed no appreciable movement (Hesse et al. 1982). Results from these studies employing conventional tags have to be interpreted on an individual basis because variables such as methods of recapture, duration of study, size of river, etc. vary widely, but, there does appear to be a portion of the population that does not move. We found that 50% and 39% of our radio-tagged fish exhibited net movements $\leq$0.11 mi in 1987 and 1988 respectively.

When movement greater than 2 miles occurs it is usually seasonal. A general consensus is channel catfish move downstream during winter months (McCammon 1956; Grace 1985; Pellett and Fago 1985). Grace (1985) found fish moved 0.8 to 87.9 miles downstream during winter months and moved farther in less severe winters. During fall and winter in Wisconsin, channel catfish move downstream 6.1 to 66.9 miles until they reach overwintering areas (Pellett and Fago 1985). Dames (1988) found upstream movement in the fall at rates greater than 164 ft/day but no movement in the winter. Channel catfish are more active in spring and summer (Stang and Nickum 1985) with spring movements both up and downstream (Dames 1988) and into tributaries (Grace 1985; Pellett and Fago 1985; Dames 1988). We observed downstream movement with means ranging from 0.1-3.3 mi in all seasons except fall of 1988 when radio-tagged fish moved upstream an average of 0.4 mi. The portion of the population moving upstream usually moves farther than the portion moving downstream (Hale et al. 1986; Dames 1988) but not always (Welker 1967). In this study the fish moving downstream moved farther than the fish moving upstream.

Dames (1988) and Hesse et al. (1982) have reported that 20 and 23% respectively of the channel catfish populations in the Missouri River move into tributaries, however, Hubley (1963) found that only 4.5% of the tagged fish moved from the Mississippi River into tributaries. We recorded 3% of our radio-tagged fish moving from the Illinois River into tributaries in 1987 and 4% moving into tributaries in 1988. Dames hypothesized that channel catfish in the Missouri River may be substituting tributaries for off-channel areas. Although many Illinois River off-channel areas have been drained and the remaining ones are threatened by sedimentation, the Missouri River has been channelized so extensively that off-channel areas are essentially non-existent.

We want to point out that in all of our observations (routine, intensive, and in relation to passage of individual tows) the radio-tagged fish were never located near the center of the 300 ft wide main channel. Rather, they were usually located in side channels and main channel border. The fish that were in the main channel were at or near the bottom of the steep decline defining the edge of the main channel border and main channel (Figures 15 and 16).

Schools of juvenile channel catfish inhabit the main channel in the late summer and fall (Starrett unpublished data; Helms 1975; Holland-Bartels and Duval 1988). Navigation may have the greatest direct impact on the channel catfish population at the juvenile life stage and the greatest indirect impact on adult members of the population since the juvenile life stages occupy the main channel and

are closer to moving tows while the adults are utilizing areas other than the main channel.

It is our conclusion that the main channel of the Illinois River in its present state is not as desirable for adult channel catfish as side channel or main channel border habitats. It is used, however, during spring (up to 38% of the locations; probably in conjunction with spawning attempts) and fall-winter (40% of the locations) when channel catfish are overwintering near the thalweg.

Bottom profiles reveal a marked contrast between the main channel and side channel in terms of diversity of depths and underwater structure (Figure 18). Maintenance dredging, moving bed loads and the propeller wash of passing tows smooth the bed of the main channel. Structures in the form of trees that are transported into the river at high flows are usually broken up by tows and/or transported to the main channel border by propeller wash. One explanation offered for the high use of side channels by riverine fish is the velocity in the side channels is significantly lower (Schramm and Lewis 1973). While we do not contest this point, we feel that there may be other factors at work. The average velocity (not average velocity at fish locations) in the side channel in this study was one third of the average velocity recorded in the main channel. But velocities at fish locations in the two different habitats were similar. It may be that average velocities are not affecting channel catfish spatial distribution but may be affecting spatial distribution of forage.

We also think the more natural state of side channels affects the fish community structure. The diversity and abundance of structures

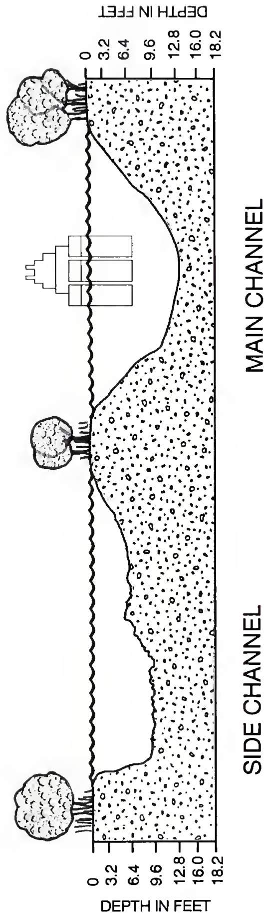


Figure 18. Comparison of bottom profiles of the main channel and side channel.

and features (consequently diversity of velocities), and diversity of depth may be attracting a diverse community with high numbers of certain species. Sylvester and Broughton (1983) concluded the larger populations and higher number of species they found in side channel and backwaters as opposed to main-channel areas was due to decreased habitat diversity in main-channel areas. In light of the loss of backwater habitat on the Missouri River (Funk and Robinson 1974), Dames (1988) concluded the channel catfish population in a portion of the Missouri River substituted lower reaches of tributaries for backwater habitat.

Currently there are three side channels between Havana and the Peoria Lock and Dam (37.8 mi) that are inundated only at relatively high river stages. The length of these abandoned channels, as side channels are called when they are only inundated at high flows, totals 6.7 mi as compared to the 3.5 mi of open side channels. Abandoned channels are natural features of alluvial rivers and during high water, are important areas for larval fishes (Conner et al. 1983) and adult gizzard shad, sunfishes, and some minnows (Sandheinrich and Atchison 1986). But active side channels are turned into abandoned channels in regulated rivers by closing structures or high sedimentation rates. Because the main channel in navigable rivers is fixed in place by levees, wing dams, closing structures, and dredging, no new side channels are allowed to form by natural meandering or cut-offs.

MANAGEMENT RECOMMENDATIONS

Since only large adult channel catfish were monitored in our study, any recommendations for management only apply to that portion of the population. Juvenile and smaller adults may behave differently and warrant further investigation.

1. Convert abandoned channels back into side channels by dredging. Currently the USACOE, U.S. Fish and Wildlife Service and Conservation agencies from the Upper Mississippi River states are evaluating the feasibility of opening select side channels on the Mississippi and Illinois rivers in conjunction with a larger plan to rehabilitate fish and wildlife habitats on both rivers (Schnick et al. 1982; USACOE 1985). A wide variety of riverine fishes including channel catfish use side channels at some life stage and would benefit from the re-openings.

2. Habitat suitability models exist for select large river fish species such as the channel catfish (McMahon and Terrell 1982), flathead catfish (Lee and Terrell 1982) and the smallmouth buffalo (*I. bubalus*) (Edwards and Twomey 1982). These models are mostly based on data from streams, small rivers, ponds and reservoirs. Information on habitat requirements of channel catfish in navigable rivers is limited. Data concerning macrohabitat and particularly microhabitat requirements are needed so habitat suitability models can be modified for large river applications. Accurate, comprehensive (e.g. all seasons, all life stages),

models will be important in evaluating and planning future rehabilitation and mitigation projects.

3. Tow-induced mortality of larval and adult fish should be quantified. A study should be undertaken with the samples taken from the tow. Larval fish change their vertical and horizontal distribution throughout the day usually moving near the surface of the main channel and backwater habitats from dusk into nighttime (Holland and Sylvester 1983) so samples should be taken both night and day. Nets and trawls should be used because fish with severed air bladders do not show up on surface counts and accurate surface counts are not possible at night. If such a study is undertaken it should span all seasons to quantify changes in mortality rates due to cooler water and impaired swimming ability, and changes in habitat selection and abundance.

EXECUTIVE SUMMARY

1) Thirty-eight channel catfish were radio tagged in 1987 and 48 in 1988. Overall 252 observations were made on 29 fish in 1987 and 729 observations were made on 36 fish in 1988.

2) High (56%) post-operative mortality and tag loss occurred in the initial set of fish radio tagged in 1987. Post-operative mortality was reduced to 25% by revising surgical implantation techniques and by radio tagging fish in April and May. Transmitter expulsion rates were estimated to be 42% in 1987 and 32% in 1988.

3) During the period of low flow and lock closure in 1987 usage of main channel habitat increased, but still was not a preferred habitat (used in the proportion it was available). Usage of backwater and temporary backwater increased with increased water levels which expanded the area and depth of the backwaters and made them accessible to the channel catfish. Following the resumption of tow traffic, as water temperatures decreased and water levels receded, usage of main channel and main channel borders increased. But use of main channel never reached the level recorded during lock closure and low flow and was never used to the extent that it was available.

4) Utilization of habitats changed with the seasons. In spring and summer side channel, main channel border, and tributary habitats were generally more preferred than backwaters and main channel. Side channel was the most preferred habitat. Fish utilized the shallow temporary backwaters created by the late summer flood in 1987. Use of backwater habitats declined in 1988 because the low water levels made these areas unsuitable. In fall the main channel border was utilized more than in any other season and was the most preferred habitat. In winter, side channel and backwaters were the most preferred habitats.

5) In the intensive study area in the summer, non-navigable channel was selected in greater proportion than it was available and navigable channel was selected in lesser proportion than it was available but the difference was not statistically significant ($P=0.11$).

6) There was no difference in selection of habitat between day and night.

7) Depths between 3.4 and 6.6 ft were selected in greater proportion than they were available in the intensive study area in the summer.

8) A portion of the radio-tagged population was sedentary with 50% and 39% of our radio-tagged fish exhibiting net movements $\leq$0.11 mi in 1987 and 1988 respectively. We found that 83% of daily movements were $\leq$0.11 mi in 1987 and 91.5% in 1988. The 10 fish that moved > 0.11 mi in 1987, moved an average net distance of 5.6 mi and the 19 fish that moved > 0.11 mi in 1988, moved an average net distance of 2.9 mi. The maximum movement recorded was downstream 27.4 mi following the late summer flood of 1987. Average gross movement for the population for both years combined was 3.6 mi.

9) Movement peaks were in the summer of 1987 and in late spring/early summer in 1988 and were also associated with fluctuations in water levels.

10) Diel movements peaked between 1600-2000 hours in 1987 and 2000-2400 hours in 1988.

11) Increases in movement during the period of lock closure were due to a late summer flood.

12) Channel catfish exhibited movement averaging 80 ft in response to 52% of the tow passages monitored.

13) When a response (detectable movement) was observed, the distance moved was positively related to the number of units in the tow.

14) Channel catfish > 131 ft from the tow responded more often than those ≤ 131 ft--probably because of wave wash and drawdown having more effect in shallow water along shore.

15) Average depths selected in spring and summer (7.25 and 6.5 ft respectively) were shallower than average depths selected in fall and winter (8.5 and 8.4 ft respectively).

16) Bottom current velocities at fish locations differed between seasons but not between day and night. Highest velocities were selected in spring (0.59 ft/s) and lowest velocities in summer (0.39 ft/s).

17) There are three side channels between Havana and the Peoria Lock and Dam (37.8 mi) that are inundated only at relatively high river stages. The length of these abandoned channels totals 6.7 mi as compared to the 3.5 mi of open side channels. Abandoned channels are natural features of alluvial rivers and are important areas for different life stages of many fishes during high water. But active side channels are turned into abandoned channels in regulated rivers by closing structures or high sedimentation rates. Because the channel in navigable rivers is fixed in place by levees, closing structures, etc. no new side channels are allowed to form. Converting abandoned channels back into side channels is feasible. A wide variety of riverine fishes including channel catfish use side channels at some life stage and would benefit from the re-openings.

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Appendix A. Date, duration, and relative water level for intensive monitoring periods.

Date	Relation to Lock Closure	Number of Hours of Monitoring	Relative Water Levels
9-10 July 1987	Before	24	Low
2-4 September 1987	During	54	High
9-10 September 1987	After	24	Low
21-22 June 1988	not applicable	24	Low
23 June 1988	not applicable	8	Low
7-8 July 1988	not applicable	11	Low
12-13 July 1988	not applicable	15	Low
4-5 August 1988	not applicable	18	Low
22-24 August 1988	not applicable	42	Low

Appendix B. Information on channel catfish radio-tagged in 1987. Frequency prefix indicates capture locatation: A=Illinois River near Anderson Lake, C=Illinois River near Chautauqua Levee, S=Spoon River, T=Illinois River near Tow Head Island.

Fish Number	Length (in.)	Weight (LBS)	Date Implanted	Last Date Alive	Minimum # of Days Alive	Died, Expelled or Failed	Number of Locations D	N	DV	NV	A	Total[1]
C1355[2]	23.0	6.1	06/03/87	06/23/87	20	DIED	3		3			6
C1209[3]	23.0	5.2	06/03/87	-	-	-						
C1439	25.0	5.8	06/03/87	07/30/87	57	EXPELLED	12	3	4			19
C1432	25.0	6.2	06/10/87	07/02/87	22	EXPELLED	2		2			4
C1455	23.0	6.0	06/10/87	07/07/87	27	UNKNOWN	4		2			6
C1406	23.5	6.1	06/10/87	-	-	DIED						
C1092	23.0	4.7	06/10/87	06/11/87	1	DIED	1					1
C0086	23.5	5.5	06/22/87	07/16/87	24	UNKNOWN	2					2
C0011	24.0	6.5	06/22/87	07/01/87	8	EXPELLED	2					2
C1447	22.0	5.0	06/22/87	07/10/87	18	UNKNOWN	4	2	1	1		8
C0036	25.0	6.5	06/22/87	11/18/87	149	ALIVE	35	4	14	4		57
C0061	23.5	4.5	06/22/87	11/18/87	149	ALIVE	7		1			8
T0210	21.5	4.7	07/02/87	07/14/87	12	UNKNOWN	7		1	1		9
T0110	21.0	4.2	07/02/87	09/21/87	81	EXPELLED	20	3	1	1		25
T0186	20.0	4.1	07/02/87	07/07/87	5	EXPELLED	2					2
T0136	20.5	3.6	07/02/87	-	-	UNKNOWN						
T0161	20.0	3.4	07/02/87	-	-	DIED						
T0236	23.5	5.8	07/06/87	07/07/87	1	DIED	1					1
S1112	21.0	3.3	07/06/87	08/12/87	37	UNKNOWN	4					4
S1088	20.5	3.3	07/08/87	08/24/87	47	UNKNOWN	4		1			5
S1012	20.0	3.2	07/08/87	08/07/87	30	LOST	3		1			4
S1038	22.5	4.6	07/08/87	08/07/87	30	LOST	1					1
S1060	24.0	5.3	07/08/87			LOST						
T1139	22.0	4.5	07/17/87	-	-	DIED						
T1161	24.0	5.5	07/17/87	-	-	DIED						
E0186	24.0	5.5	08/13/87	EXPERIMENTAL		DIED						
E0161	22.0	4.7	08/13/87	EXPERIMENTAL		SACRIFICED						
T1092[4,5]	25.5	6.0	08/21/87	09/17/87	27	EXPELLED	8	5	2			15
T1139[4,5]	24.0	5.7	08/21/87	09/01/87	11	EXPELLED	3					3
C0471[4]	24.0	6.5	08/21/87	10/19/87	59	ALIVE	11					11
C0011[4,5]	23.5	5.0	08/21/87	10/19/87	59	UNKNOWN	17	3	2	2		24
C1161[4,5]	23.5	6.0	08/21/87	09/02/87	12	DIED	3	1	1			5
T0498[6]	22.0	4.0	08/21/87	08/31/87	10	DIED	1					1
C0161[5,6]	24.0	5.7	08/25/87	10/22/87	58	DIED	1					1
T0186[5,6]	22.0	4.5	08/25/87	10/19/87	55	ALIVE	4					4
C1432[5,6]	23.5	5.3	08/27/87	09/04/87	8	ALIVE	7	3	2			12
A0161[5]	22.0	4.1	10/13/87			?	4		1			5
A1439[5]	22.5	5.7	10/13/87	03/30/88	168	?	5		2			7

[1] D=Daytime, N=Nighttime, DV=Daytime with velocity measurement, NV=Nighttime with velocity measurement, A=Airplane, Total=Total number of observations

[2] Female still with eggs

[3] Experimental transmitter, limited broadcasting range

[4] Implanted date shown, held in tank for postoperative care until 08/25/87.

[5] Reimplanted transmitter

[6] Implanted date shown, held in tank for postoperative care until 08/31/87

Appendix C. Information on channel catfish radio-tagged in 1988.

Fish Number	Date Implanted	Last Date Located	Minimum # days Alive	Number of Locations D	N	DV	NV	A	Tot[1]	Length (in.)	Weight (lbs)	Sex	Battery	Comments	Capture Location
48.111	04/19/88	05/23/88	34	3				1	4	21.50	4.2		1/2A		Chau.Leve
48.038	04/19/88									24.00	6.0		2/3A		Chau.Leve
48.063	04/26/88	05/10/88	14	1					1	21.50	4.8		2/3A		Dog F. Lk
48.013	04/26/88	07/10/88	75	18	4	4	3		29	23.00	5.5		2/3A		Dog F. Lk
48.311	05/03/88	05/16/88	13	2					2	24.00	5.5		2/3A		Mud L Isl
49.872	05/03/88	07/22/88	80	5				1	6	25.50	8.1		ATS	ATS 3 mo	Mud L Isl
48.411	05/04/88	10/25/88	174	33	12	2	3		50	24.00	5.4		1/2A		
49.900	05/04/88	07/25/88	82	32	15	9	6		62	23.00	5.8		ATS	ATS 3 mo	
48.336	05/04/88									25.00	8.8		2/3A		
48.362	05/04/88									27.75	10.6		2/3A		
48.385	05/05/88	08/17/88	104	5				2	7	22.00	4.5		1/2A		
49.137	05/05/88	08/18/88	105	14		1			15	23.00	4.3	F	2/3A	Last yrs	
49.942	05/05/88	08/19/88	106	19	14	2	1		36	25.50	7.5		ATS	ATS 3 mo	
49.092	05/05/88	05/23/88	18	1				1	2	20.50	4.1		1/2A	Last yrs	
48.497	05/13/88	05/23/88	18	1				1	2	22.50	5.1	F	1/2A	Last yrs	
48.484	05/17/88	07/25/88	69	28	15	8	14		65	23.50	7.3		2/3A		
48.461	05/17/88									23.50	5.1		2/3A		
48.562	05/17/88									21.50	4.6		1/2A		
48.288	05/18/88	06/01/88	14	1		1			2	22.50	6.3		2/3A	repaired	THI
48.162	05/18/88	07/05/88	48	4		2			6	24.50	6.9	F	1/2A	repaired	Chau.Leve
48.511	05/18/88	10/06/88	141	6		3			9	25.00	8.5		2/3A		THI
48.237	05/18/88									25.00	7.5		2/3A	repaired	THI
48.536	05/18/88									25.50	7.8	F	1/2A		Chau.Leve
48.137	05/19/88	10/17/88	151	12		1			13	23.00	6.7		1/2A	repaired	Matanza
48.761	05/19/88	11/10/88	175	27	12	2	3		44	27.50	9.8		1/2A		Matanza
48.186	05/19/88	06/09/88	21	1	1	1			3	26.00	7.0		1/2A	repaired	Matanza
48.213	05/19/88	07/14/88	56	7		1		1	9	26.00	7.1		2/3A	repaired	Matanza
48.734	05/19/88									22.50	5.4		2/3A		Matanza
48.660	05/24/88	06/24/88	31	5	1				6	22.50	6.0	F	2/3A	new style	2 from
48.587	05/24/88	08/19/88	87	15	1	2			18	22.50	5.4	F	2/3A	new style	THI
48.711	05/24/88	07/28/88	65	8		1		1	10	23.50	6.4	F	2/3A	new style	3 from
48.788	05/24/88	07/12/88	49	10	6	4	3		23	22.00	5.3	F	2/3A	new style	Chaut.
48.687	05/24/88	11/10/88	170	46	20	7	8		81	20.20	4.4	F	2/3A	new style	"
48.862	05/25/88									21.50	4.9	F	1/2A		THI
49.013	05/25/88	07/25/88	61	25	17	8	7		57	20.50	4.0	F	1/2A		THI
48.911	05/25/88	06/24/88	30	16	8	6	2		32	22.50	4.9	M	2/3A		THI
48.986	05/25/88	08/18/88	85	36	20	5	7		68	22.50	5.3	M	1/2A		THI
48.962	05/25/88									22.00	5.8	F	2/3A		THI
48.611	05/25/88	10/24/88	152	8					8	24.00	5.5	M	2/3A		THI
49.051	05/25/88									22.00	4.9	F	1/2A		THI
49.036	05/25/88									22.00	5.4		1/2A		THI
48.888	10/03/88	12/16/88	74	8					8	19.00	3.0		1/2A		Chau.Leve
48.088	10/03/88	12/08/88	66	9					9	23.5	5.9		2/3A		Chau.Leve
48.111B	10/03/88	12/08/88	66	11					11	22.00	4.6		2/3A		Chau.Leve
48.638	10/04/88	12/08/88	65	12					12	26.00	7.9		2/3A		Chau.Leve
48.837	10/04/88	11/10/88	37	7					7	20.50	3.8		1/2A		Chau.Leve
48.237	10/05/88	10/24/88	9	3					3	23.00	5.1			13P/15S	THI
48.814	10/11/88	12/08/88	58	9					9	22.00	4.2		1/2A		Chau.Leve

[1] D=Daytime, N=Nighttime, DV=Daytime with velocity measurement, NV=Nighttime with velocity measurement, A=Airplane, Total=Total number of observations

Appendix D. Select environmental parameters measured in 1987.

Date	Fish #	Time	Habitat[1]	Dissolved Oxygen Conc. (ppm) Surface	Dissolved Oxygen Conc. (ppm) Bottom	Water Temp. (^{o}F) Surface	Water Temp. (^{o}F) Bottom	Secchi (in)	Conductivity (umhos/cm) Surface
06/03/87	C1209								550
06/04/87	C1439								560
06/08/87	C1439								560
06/15/87	C1355	1040	SC		4.6		84.0		
06/15/87	C1439	1110	MC		5.4	84.0	82.0		
06/18/87	C1432	1000	MCB		5.9	84.0	82.9		
06/18/87	C1355	1100	SC		5.2	84.9	84.6		
06/18/87	C1455	1120	MC		6.3	84.7	83.7		
06/18/87	C1439	1140	MCB		6.9	84.7	84.4		
07/02/87	C1432	2015	MCB	6.6		79.0			
07/06/87			TRIB			86.0	79.7		560
07/09/87	T0210	1420	SC		6.7	85.6	84.9		
07/09/87	C0036	1500	MCB		6	83.8	83.8		
07/09/87	C1439	1530	MC		5.7	84.0	83.3		
07/09/87	C1447	1550	MC		5.7	84.2	83.3		
07/09/87	T0210	2219	SC		6	83.5	83.7		
07/09/87	C0036	2309	MCB		5.7	83.7	83.7		
07/10/87	C1447	24	MCB		5	83.3	83.3		
07/16/87	C0086	1300	MC					12.4	
07/17/87	T0210	1250	MCB	8.4	8.1	79.9	79.3	12.2	
07/27/87	S1088	1430	TRIB	6.9	2.7	90.0	86.9		
07/27/87	S1112	1449	TRIB	6.9	1.1	90.1	87.1		
07/27/87	T0210	1518	MCB	5.3	4.4	88.3	87.6	13.5	650
07/28/87	C0036	1045	MCB	4.3	4	86.4	86.5		
07/30/87	C0036	945	MCB					13.7	
08/05/87	C0036	1450	MCB	4.6	3.6	87.6	86.7	13.0	
08/10/87	C0036	1430	MCB	6.8	6.5	83.7	83.5	10.9	
08/17/87			MC					9.5	
08/18/87			MC					8.5	
08/20/87	C0036	1103	SC	4.5	4.2	81.5	81.3		
08/20/87	T0110	1200	SC	4.9	4.8	80.8	80.6		
08/20/87	C0036	1230	SC	4.5	4.3	81.3	81.1	10.7	
08/26/87			MC					10.7	
09/01/87	C1161	1500	SC					9.0	
09/02/87	T1092	1730	MCB	6.7	6.4	71.6	71.4		
09/02/87	C1161	1946	SC	5.7	5.8	71.1	71.1		
09/02/87	T0110	2003	TBW	6.2	6.2				
09/02/87	C0036	2019	TBW	6.5	6.5	70.9	70.9		
09/02/87	C0011B	2100	SC	6.5	6.3	70.3	70.5		
09/03/87	T1092	357	MCB	5.3	5.5	69.1	69.4		
09/03/87	T1092	856	MCB	5.6	4.9	69.4	69.3		
09/03/87	C1432B	1000	BW	9.6	6.3	70.2	69.4		
09/03/87	C0011B	1205	SC	6.1	4.8	72.3	70.7		
09/03/87	T1092	1705	MCB	8.3	6.2	73.4	72.5		
09/03/87	C1432B	1730	BW	13.3	5.8	75.6	72.1		
09/03/87	C0011B	1919	SC	6.4	5.8	70.9	70.9		
09/04/87	T1092	50	MCB	5.2	5	70.2	70.2		
09/04/87	C1432B	135	BW	8	8.1	70.9	71.2		
09/04/87	C0036	236	SC	5.5	5.6	70.5	70.7		
09/04/87	T0110	316	TBW						
09/04/87	C0011B	433	SC	5.7	5.7	70.2	70.2		
09/04/87	T1092	832	MCB					7.5	
09/04/87	T1092	1135	MCB	5	4.3	71.4	70.5		

Appendix D cont. Select environmental parameters measured in 1987.

Date	Fish #	Time	Habitat[1]	Dissolved Oxygen Conc. (ppm) Surface	Dissolved Oxygen Conc. (ppm) Bottom	Water Temp. (°F) Surface	Water Temp. (°F) Bottom	Secchi (in)	Conductivity (umhos/cm) Surface
09/04/87	C1432B	1202	BW	10.9	6	74.8	72.3		
09/04/87	C0036	1239	SC	5.7	5	70.7	70.5		
09/04/87	C0011B	1340	SC	5.5	5.1	71.2	71.1	8.5	
09/08/87	C0036	1029	MCB	6.1	5.8	75.9	75.9		
09/08/87	T1092	1205	BW	6.5	6.2	77.2	76.6		
09/08/87	C0036	1615	MCB					12.5	
09/14/87			MC					11.0	
09/21/87	T0110	1345	TBW	5.5	5.5	67.1	67.1		
09/21/87	C0036	1420	MCB	7.2	6.9	68.4	68.2	10.0	
09/21/87	C0011B	1450	SC	7.8	7.4	68.4	68.4		
09/24/87	C0011B	927	SC					11.0	
09/28/87	C0471	943	BW	8.7	5.2	69.1	68.5		
09/28/87	C0011B	947	BW	7.5	2.2	69.4	68.4		
09/28/87	C0036	1027	MCB					11.5	
10/05/87	C0471	930	BW	9.8	2	52.7	52.7	11.0	
10/05/87	C0036	1010	MCB	9.5	9.2	56.1	56.1	11.0	
10/05/87	C0061	1050	MC	9.4	9.3	56.5	56.3		
10/07/87			MC					11.5	
10/19/87	C0011B	1226	MC	9.8	9.8	55.0	55.0		
10/19/87	C0036	1357	MCB	9.2	9.2	55.8	55.8		

[1] Habitat designations: MC=Main Channel, MCB=Main Channel Border, SC=Side Channel Border, BW=Back Water, TBW=Temporary Back Water, TRIB=Tributary stream

Appendix E. Select environmental parameters measured in 1988.

Date	Fish #	Time	Habitat[1]	Dissolved Oxygen Conc. (ppm) Surface	Dissolved Oxygen Conc. (ppm) Bottom	Water Temp. (°F) Surface	Water Temp. (°F) Bottom	Secchi (in)	Cond. (umhos/cm) Surface	pH	NH_4 (ppm)	(NH_3-N) (ppm)
03/18/88	1439	1300	MCB			40.1						
03/30/88	1439	1115	MCB	9.5	8.9	49.6	49.5		410			
04/08/88	1439	1115	BW			55.4	55.4		455			
05/02/88	63	931	BW	17.2	18.0	61.9	61.5		500			
05/05/88	13	1330	SC			64.4						
05/06/88	13	1005	SC	9.0	9.2	65.8	65.7					
05/06/88	13	1400	SC	11.4	9.9	67.5	66.2					
05/10/88	13	955	SC			68.0			600			
05/11/88	13	1110	SC						600			
05/11/88	311	1412	MCB			68.9						
05/13/88	1137	1228	BW	9.0	8.0	73.0	72.7		620			
05/13/88	1942	1403	MCB	8.0	8.0	70.5	70.2					
05/13/88	13	1420	MCB	8.0	8.0	70.3	69.8					
05/13/88	1900	1432	SC	8.0	7.0	69.6	69.4					
05/16/88	1900	915	SC			70.7		13.0	650			
05/20/88	411	1200	MC	8.4		70.9						
05/24/88	1900	1514	SC			75.2		5.9	610			
06/01/88	288	900	MCB	7.0	6.6	76.5	76.3					
06/01/88	510	1020	SC	7.6	7.5	77.2	77.0					
06/01/88	1942	1032	SC	8.0	6.2	79.2	76.1					
06/01/88	587	1245	MCB	9.1	8.3	79.0	77.9					
06/01/88	162	1540	MC	9.1	8.1	78.8	78.1					
06/02/88	162	2000	MCB	8.1		80.1						
06/02/88	687	2142	MCB	8.2	8.2	79.9	80.1					
06/02/88	1013	2250	MC	8.3	8.1	79.7	79.9					
06/02/88	484	2335	MCB	8.1	8.1	79.3	79.7					
06/04/88	137	850	MCB	7.7		77.0						
06/06/88	484	755	MCB	7.2	6.4	75.7	76.3					
06/06/88	1900	1010	SC	7.7	6.8	77.7	77.2					
06/06/88	510	1023	SC	7.6	7.4	77.4	77.2					
06/06/88	911	1050	MCB	7.5	7.0	77.2	77.0					
06/07/88	687	845	MC	7.5	6.7	77.0	77.0					
06/07/88	213	925	MCB	7.5	7.4	77.4	77.2					
06/07/88	1013	1020	MC	7.9	7.3	77.9	77.2					
06/07/88	711	1230	TRIB	12.4	10.2	77.5	76.6					
06/08/88	788	920	SC	6.7	6.7	77.0	77.2					
06/08/88	510	935	SC	6.2	6.0	76.3	76.5					
06/09/88	587	945	MCB	5.1	4.6	73.6	73.8	13.4				
06/09/88	162	1107	MCB	5.2	5.4	74.1	74.1					
06/09/88	186	1230	MC	6.2	5.2	75.0	74.5					
06/09/88	137	1355	MCB	6.2	5.8	75.7	75.7	13.4				
06/14/88	162	1045	MCB			75.2						
06/14/88	788	1334	SC						725			
06/15/88	711	945	TRIB			78.8		9.8	575			
06/15/88	1013	1200	MC			77.9		11.8	775			
06/16/88	761	1130	MC					9.1	790			
06/16/88	1137	1440	MCB	7.5		80.6						
06/21/88	911	846	MCB	6.0	5.7	81.7	81.3					
06/21/88	484	900	MCB	5.6	5.6	81.7	81.5					
06/21/88	1013	915	MC	6.1	5.4	82.2	81.7					
06/21/88	1900	936	SC	6.0	5.3	82.0	81.7					
06/21/88	986	949	SC	6.4	5.5	82.0	81.7					

Appendix E cont. Select environmental parameters measured in 1988.

Date	Fish #	Time	Habitat[1]	Dissolved Oxygen Conc. (ppm) Surface	Dissolved Oxygen Conc. (ppm) Bottom	Water Temp. (^oF) Surface	Water Temp. (^oF) Bottom	Secchi (in)	Cond. (umhos/cm) Surface	pH	NH_4 (ppm)	(NH_3-N) (ppm)
06/21/88	687	1003	MC	6.2	5.5	82.4	82.0					
06/21/88	911	1241	MCB	7.7	6.0	84.6	82.4	14.2	800			
06/21/88	484	1250	MCB	7.6	5.8	84.4	82.4					
06/21/88	1013	1302	MC	7.8	5.3	84.2	82.2					
06/21/88	1900	1327	SC	6.9	6.2	83.8	83.1					
06/21/88	986	1336	SC	6.9	6.1	83.5	82					
06/21/88	687	1354	MCB	6.5	5.6	84.7	82.8					
06/21/88	911	1642	MCB	7.3	6.1	85.8	83.5					
06/21/88	484	1652	MCB	6.6	5.9	84.2	83.7					
06/21/88	1013	1659	MC	6.5	6.0	83.8	83.3					
06/21/88	1900	1719	SC	6.7	6.1	84.0	83.7					
06/21/88	986	1726	SC	6.5	5.9	83.7	83.5					
06/21/88	687	1748	MCB	6.6	6.6	88.3	83.8					
06/21/88	484	2155	MCB	5.8	5.6	83.1	83.3					
06/21/88	911	2205	MC	5.8	5.6	82.9	82.9					
06/21/88	1013	2217	MC	5.6	5.7	82.9	82.9					
06/21/88	986	2230	SC	5.3	5.5	82.9	82.9					
06/21/88	1900	2240	SC	5.6	4.8	82.8	82.9					
06/22/88	687	255	MCB	5.1	5.2	82.8	82.8					
06/22/88	911	310	MCB	5.3	5.2	82.8	82.6					
06/22/88	484	320	MCB	5.1	5.1	81.5	81.7					
06/22/88	1013	330	MC	5.2	5.2	82.8	82.9					
06/22/88	986	338	SC	5.0	5.0	82.4	82.4					
06/22/88	1900	350	SC	5.1	5.0	81.9	81.9					
06/22/88	911	605	MCB	5.0	5.0	82.2	82.2					
06/22/88	484	610	MCB	5.2	5.0	81.9	82.0					
06/22/88	1013	618	MC	4.9	4.9	82.8	82.8					
06/22/88	986	627	MCB	5.0	5.1	82.0	82.2					
06/22/88	1900	636	SC	5.0	4.9	82.0	82.0					
06/22/88	687	649	MCB	5.0	4.9	82.8	82.8					
06/23/88	911	1500	MCB	5.9	5.0	84.0	83.7					
06/23/88	687	1635	MCB	5.6	5.3	84.7	84.4					
06/23/88	484	1657	MCB	5.2	4.8	84.7	83.7					
06/23/88	1013	1742	MC	5.2	4.8	83.8	83.7					
06/23/88	1900	1813	SC	5.2	5.1	84.0	83.8		800			
06/23/88	986	1835	SC	5.4	4.8	83.8	83.8					
06/23/88	687	2101	MCB	4.7	4.6	83.3	83.5					
06/23/88	484	2113	MCB	5.0	4.8	83.5	83.5					
06/23/88	911	2118	MCB	5.1	4.7	83.5	83.5					
06/23/88	1013	2125	MC	4.9	4.7	83.3	83.5					
06/23/88	1900	2144	SC	4.7	4.5	83.3	83.3					
06/23/88	986	2151	SC	5.3	5.1	83.1	83.1					
06/23/88	687	2258	MCB	4.9	4.7	82.9	83.1					
06/23/88	484	2307	MCB	4.7	4.5	83.1	83.1					
06/23/88	911	2316	MCB	4.9	4.6	83.1	83.3					
06/23/88	1013	2323	MC	4.8	4.6	83.1	83.3					
06/23/88	986	2331	SC	4.9	4.7	82.9	82.9					
06/23/88	1900	2339	SC	4.7	4.5	82.9	82.9					
06/24/88	213	1030	TRIB	6.7	5.9	82.9	82.4		550			
06/24/88	711	1050	TRIB	6.5	5.6	82.4	82.2					
06/29/88	687	1125	MC	5.3	5.0	79.5	79.7					
06/29/88	1137	1345	MCB	5.8	5.5	79.0	79.0	11.0		8.2		

Appendix E cont. Select environmental parameters measured in 1988.

Date	Fish #	Time	Habitat[1]	Dissolved Oxygen Conc. (ppm) Surface	Dissolved Oxygen Conc. (ppm) Bottom	Water Temp. (^{o}F) Surface	Water Temp. (^{o}F) Bottom	Secchi (in)	Cond. (umhos/cm) Surface	pH	NH_4 (ppm)	(NH_3-N) (ppm)
06/29/88	1872	1455	MC	5.3	5.2	78.8	79.0					
07/05/88	711	1130	TRIB	6.9	3.8	82.4	79.0	10.6	580	8.2		
07/05/88	687	1400	MCB	8.4	5.6	80.6	77.5	11.8	790	6.1		
07/07/88	1013	2104	MC	4.6	4.1	82.9	82.6					
07/07/88	788	2130	SC	4.1	4.1	82.6	82.8					
07/07/88	1900	2141	SC	4.5	4.3	82.8	82.9					
07/07/88	484	2154	MCB	4.0	3.9	82.6	82.8					
07/07/88	13	2204	MCB	4.8	4.1	82.6	82.8					
07/07/88	687	2220	MC	4.2	4.0	82.6	82.8					
07/08/88	1013	122	MC	3.9	3.7	82.6	82.6					
07/08/88	788	145	SC	3.7	3.5	82.2	82.4					
07/08/88	1900	200	SC	3.7	3.6	82.4	82.6					
07/08/88	484	216	MCB	3.9	3.8	82.2	82.2					
07/08/88	13	233	MCB	3.9	3.9	81.9	81.9					
07/08/88	687	249	MC	3.7	3.6	82.9	83.1					
07/08/88	1013	625	MC	3.4	3.3	82.6	82.8					
07/08/88	788	643	SC	3.3	3.2	81.9	81.7					
07/08/88	1900	654	SC	3.2	3.2	82.4	82.6					
07/08/88	13	709	SC	3.6	3.4	82.8	82.8					
07/08/88	484	718	MCB	3.6	3.4	82.6	82.4					
07/08/88	687	729	MCB	3.5	3.4	83.1	83.1					
07/08/88	986	730	BW	4.5	4.4	74.7	74.1					
07/10/88	484	903	MCB	3.9		84.2						
07/12/88	1013	1344	MC	3.6	3.2	84.7	84.7					
07/12/88	788	1530	SC	4.2	3.7	85.1	84.9					
07/12/88	1900	1550	SC	3.5	3.4	84.2	84.4					
07/12/88	986	1600	SC	3.4	3.2	84.2	84.4					
07/12/88	484	1642	MCB	3.8	4.0	83.8	83.8					
07/12/88	687	2035	MCB	3.4	3.3	84.4	84.4					
07/12/88	1013	2053	MC	3.4	3.3	84.4	84.4					
07/12/88	788	2105	SC	3.6	3.6	83.5	83.7					
07/12/88	1900	2114	SC	3.4	3.1	84.0	84.2					
07/12/88	986	2123	SC	3.3	3.2	84.4	84.2					
07/12/88	484	2130	MCB	3.3	3.4	84.0	84.0					
07/12/88	687	2359	MCB	3.4	3.3	84.6	84.9					
07/13/88	1013	5	MC	3.6	3.3	84.6	84.6					
07/13/88	788	27	SC	3.4	2.9	83.3	83.5					
07/13/88	1900	36	SC	3.5	3.1	83.8	83.8					
07/13/88	986	44	SC	3.5	3.3	84.0	84.2					
07/13/88	484	56	MCB	3.5	3.4	83.8	84.2					
07/13/88	986	307	SC	3.5	3.4	84.4	84.6					
07/13/88	484	324	MCB	3.8	3.6	83.8	84.0					
07/13/88	687	610	MC	3.5	3.3	84.4	84.6					
07/13/88	1013	622	MC	3.5	3.2	84.4	84.6					
07/13/88	788	633	SC	3.4	3.0	83.8	83.7					
07/13/88	1900	642	SC	3.3	3.2	84.2	84.0					
07/13/88	484	654	MCB	3.5	3.3	83.5	83.7					
07/13/88	986	706	MCB	3.4	3.2	84.4	83.8					
07/14/88	1137	1035	MC	4.3	3.8	84.4	84.4					
07/14/88	711	1525	TRIB					12.2	800			
07/19/88	1137	915	MCB	3.9		86.5						
07/21/88		1510	MC	5.4		84.2			790	8.4		

Appendix E cont. Select environmental parameters measured in 1988.

Date	Fish #	Time	Habitat[1]	Dissolved Oxygen Conc. (ppm) Surface	Dissolved Oxygen Conc. (ppm) Bottom	Water Temp. (^{o}F) Surface	Water Temp. (^{o}F) Bottom	Secchi (in)	Cond. (umhos/cm) Surface	pH	NH_4 (NH_3-N) (ppm) (ppm)
07/22/88		1415	MC	5.9		82.8				8.4	
07/25/88	1942	927	SC				80.6				
07/28/88	711	1515	TRIB	9.5	4.7	89.2	82.4				
07/28/88		1600	MC	6.9	5.7	85.5	84.4	12.2			
08/01/88	1137	1015	MC	4.4	3.1	86.9	85.8			8.4	
08/01/88	687	1200	MCB	5.1	3.8	87.8	86.5				
08/01/88	986	1220	SC	5.3	4.7	88.3	86.9				
08/03/88	761	1050	MCB	3.8		87.4		13.4	740	8.4	
08/03/88	587	1515	MCB	5.7		89.4		11.8		8.6	
08/04/88	687	2030	MC	4.3	4.1	88.3	88.5				
08/04/88	986	2057	SC	4.4	4.3	88.3	88.3				
08/05/88	687	4	MCB	4.2	4.0	88.0	88.2				
08/05/88	986	25	SC	4.1	4.0	87.8	88.0				
08/05/88	1942	310	SC	3.5	3.3	87.1	87.1				
08/05/88	986	342	SC	3.8	3.8	87.6	87.8				
08/08/88	687	1225	MCB	4.0		86.4		13.0	780	8.7	
08/09/88		1245	MC	2.9			86.5	15.0	650	8.6	
08/15/88	137	1357	SC	4.9	3.1	90.0	86.4	12.6			
08/16/88	1942	2125	SC	3.6	3.3	89.4	88.5				
08/16/88	1942	2330	SC	3.3	2.9	88.7	88.3				
08/18/88	1137	745	MCB	3.6	3.3	88.2	88.3				
08/18/88	687	905	MCB	3.9	3.6	88.3	88.3				
08/18/88	587	1100	MCB	3.8	3.5	88.9	88.3				
08/18/88	411	1115	MCB	4.2	3.9	88.7	88.2				
08/18/88	1942	1225	SC	5.1	3.0	89.2	87.8				
08/19/88	587	950	MCB	3.0		87.8		11.0		8.2	
08/22/88	761	1449	MCB	3.7	3.3	84.0	83.8				
08/22/88	411	1526	MCB	4.0	4.0	83.8	83.7				
08/23/88	761	44	MC	3.4	3.3	82.6	82.8				
08/23/88	411	111	MCB	3.3	3.1	82.0	82.2				
08/23/88	761	804	MCB	3.2	2.9	81.5	81.7				
08/23/88	411	823	MCB	3.5	3.3	81.0	81.0				
08/23/88	761	2325	MCB	4.1	3.9	81.7	82.0				
08/23/88	411	2345	MCB	4.0	4.0	81.7	81.9				
08/24/88	761	217	MC	4.0	3.8	81.5	81.7				
08/24/88	411	237	MCB	3.7	3.6	81.0	81.3				
08/29/88		935	SC	4.7	3.0	72.9	73.0	9.4	600	8.9	0.70(0.23)
08/29/88		1210	MC	5.6	5.3	74.7	74.3	10.6	625	8.3	0.95(0.05)
09/01/88		1039	MC	4.7		73.4				8.4	0.82(0.11)
09/06/88		1219	TRIB	4.7		69.1		7.9	550	8.7	0.95(0.11)
09/06/88		1319	MC	6.4		72.3		12.2	550	8.5	1.10(0.14)
09/12/88		1322	MC	6.7		72.1		10.2	625	8.7	
09/19/88		920	MCB	5.3		74.7		11.8	590	8.5	1.30(0.19)
09/20/88		820	MCB	6.5		71.4		11.8	590	8.5	0.65(0.08)
09/28/88		950	SC	8.5	6.9	66.2	69.8		575		
09/28/88	687	1030	MC	8.6		70.3			590		
09/28/88		1150	TRIB	7.5	5.8	68.7	66.7		580	8.5	
09/28/88		1215	MC							8.6	
10/13/88	687	1040	MCB			59.0					
10/13/88		1047	MC			59.0			490	8.6	
10/17/88	761	909	MCB	8.3	7.4	60.3	60.1				
10/18/88	888	1252	MC	8.9	8.1	60.6	60.4				

Appendix E cont. Select environmental parameters measured in 1988.

Date	Fish #	Time	Habitat[1]	Dissolved Oxygen Conc. (ppm) Surface	Bottom	Water Temp. (^{o}F) Surface	Bottom	Secchi (in)	Cond. (umhos/cm) Surface	pH	NH_4 (ppm)	(NH_3-N) (ppm)
10/18/88		1307	MC	8.9	8.0	60.6	60.4		500	8.7		
10/18/88	111B	1350	MC	7.0	6.9	60.8	60.6					
10/18/88	837	1415	MC	7.8	7.4	60.8	60.6					
10/20/88		1300	MC	8.1	7.9	58.8	59.0		490	8.9	0.60	(0.13)
11/07/88	837	1030	MC	9.8	8.9	47.3	47.3					
11/07/88	111B	1045	MCB	9.8	9.0	47.3	47.3					
11/07/88	638	1120	MC	9.2	8.8	47.5	47.3					
11/07/88	88	1303	MCB	9.2	8.8	48.2	48.2					
11/07/88	814	1410	BW	6.0	6.0	45.3	43.7					
11/14/88	111B	1140	MCB	10.8	9.8	45.3	45.1					
11/14/88	638	1149	MC	10.5	9.6	45.1	45.1					
11/14/88	88	1259	MCB	10.4	9.8	46.2	46.0					
11/14/88	888	1343	MCB	10.1	9.9	46.0	45.9					
11/14/88	814	1414	BW	8.8	7.7	47.1	45.3					
11/28/88	111B	1120	MC	13.3	10.8	44.2	44.2		400			
11/28/88	638	1137	MC	9.3	9.1	44.2	44.2					
11/28/88	814	1232	BW	10.3	9.3	37.6	37.6					
01/19/89		1302	MCB			37.4	37.4	9.1	470	8.7		
01/19/89		1445	BW			41.0						
01/19/89		1501	SC			37.4						
01/24/89			MCB			33.8						

[1] Habitat designations: MC=Main Channel, MCB=Main Channel Border, SC=Side Channel Border, BW=Back Water, TRIB=Tributary stream

Appendix F. Summary of radio-tagged channel catfish movements.

1987

	Distance Moved (mi.)		Frequency and Distance Moved (mi.)				
Fish #	Gross	Net	≤0.1	>.11 - 1.0	>10.0	Total	Comments
A0161	0.0	0.0	1	0	0	1	
A1439	0.1	-0.1	2	0	0	2	
C0011	0.0	0.0	1	0	0	1	
C0011B	16.7	11.9	22	1	2	25	
C0036	6.5	-0.1	40	11	1	52	
C0061	0.0	0.0	5	0	0	5	
C0086	8.4	-8.4	0	0	1	1	
C0471	3.2	+0.2	7	1	2	10	
C1161	0.0	0.0	4	0	0	4	
C1355	0.0	0.0	2	0	0	2	
C1432	0.0	0.0	2	0	0	2	
C1432B	0.1	-0.1	8	0	0	8	
C1439	4.3	-4.7	13	3	2	18	
C1447	0.0	0.0	9	0	0	9	
C1455	1.0	0.0	3	2	0	5	
S1012	4.9						Spoon River
S1038	9.9						Spoon River
S1088	3.3						Spoon River
S1112	2.3						Spoon River
T0110	4.8	+2.7	26	5	2	33	
T0186B	0.0	0.0	2	0	0	2	
T0210	0.3	-0.1	12	1	0	13	
T1092	27.6	-27.4	13	0	1	14	
T1139	0.0	0.0	1	0	0	1	
	Mean	Summary					
N = 24	3.9	*	173	24	11	208	
			(83%)	(11.5%)	(5.3%)		

* Summary of Net Movements

Direction	# of Fish	Distance Moved (mi.) (Mean)
Upstream (+)	2	1.5
No Movement (0)	10	-
Downstream (-)	8	6.6

Appendix G. Summary of radio-tagged channel catfish movements.

1988

	Distance Moved (mi.)		Frequency and Distance Moved (mi.)				
Fish #	Gross	Net	≤0.1	>.11 - 1.0	>10.0	Total	Comments
111B	4.3	+0.1	9	0	2	11	
0013	7.4	-0.1	19	6	2	27	
0088	0.4	0.0	8	0	0	8	
0137	14.1	-14.1	11	1	1	13	
0162	0.2	+0.2	4	1	0	5	
0186	0.3	-0.3	1	1	0	2	
0213	3.3	-	9	0	2	11	Moved up Spoon River
0237	0.0	0.0	3	0	0	3	
0288	0.0	0.0	1	0	0	1	
0311	0.0	0.0	1	0	0	1	
0385	0.0	0.0	3	0	0	3	
0411	10.4	-9.0	47	2	1	50	
0484	0.5	-0.1	58	0	0	58	
0518	12.6	-12.0	9	0	1	10	
0587	16.4	-3.6	12	2	2	16	
0611	0.0	0.0	9	0	0	9	
0638	5.2	-3.2	7	5	1	13	
0660	0.0	0.0	5	0	0	5	
0687	3.1	-0.1	78	0	0	78	
0711	1.4	-	8	0	1	9	Moved up Spoon River
0761	0.4	0.0	44	0	0	44	
0788	0.8	0.0	24	4	0	28	
0814	0.8	-0.2	5	3	0	8	
0837	3.0	+2.8	6	1	1	8	
0888	5.7	+5.5	5	0	2	7	
0911	0.4	0.0	27	0	0	27	
0986	5.4	0.0	66	5	0	71	
1013	1.0	0.0	56	0	0	56	
1137	2.9	+2.3	16	0	1	17	
1439	0.2	-0.2	3	1	0	4	
1872	1.3	+0.3	2	3	0	5	
1900	2.0	-1.0	61	1	0	62	
1942	5.9	-0.9	27	5	2	34	
	Mean	Summary					
N = 33	3.3	*	644 (91.5%)	41 (5.8%)	19 (2.7%)	704	

* Summary of Net Movements

Direction	# of Fish	Mean Distance Moved (mi.)
Upstream (+)	6	1.9
No Movement (0)	12	-
Downstream (-)	13	3.4

Appendix H. Information on radio-tagged channel catfish behavior during passage of individual tows.

FISH #	DATE	START TIME	DURATION OF MONIT. (min)	MINIMUM DIST. TO TOW (ft)	CONFIG-URATION	N OF UNITS	DIRECT. (UP OR DOWN)	CAPACITY	RESPONSE (Y or N)	MOVEMENT (ft)	HABITAT[1] BEFORE PASSAGE	HABITAT AFTER PASSAGE	DEPTH BEFORE PASSAGE (ft)	DEPTH AFTER PASSAGE (ft)
C0036	07/09/87	1755	8	66	3X5	15	D	F	N		MCB	MCB	4.9	
1092	09/02/87			98	2x3+1	7	U	E	N		MCB	MCB	1.6	
1092	09/02/87	2203	6	230	2X5	10	D	P	N		MCB	MCB	1.6	
1092	09/02/87	1330	35	230	2X2	4	D	P	N		MCB	MCB		
1092	09/02/87	2209	10	230	2x5	10	U	P	N		MCB	MCB		
C0036	09/09/87	1253	9	197	2X4+3	11	D	F	Y	131	MCB	MCB		
C0036	09/09/87	1710	76	197	3X4	12	U	P	Y	49	MCB	MCB	10.5	
C0036	09/09/87	2000	29	197	2X2+1	5	U	E	Y	66	MCB	MCB	8.2	7.9
C0036	09/10/87	1	55	197	2X5	10	U	P	Y	59	MCB	MCB		
C0036	09/10/87	604	10	197	2X5	10	U	F	N		MCB	MCB		
C0036	09/10/87	1120	47	197	2X4	8	U	F	Y	115	MCB	MCB		
C0036	09/14/87	1243		49	1x1	1	U	F	Y	16	MCB	MCB	13.1	13.1
1013	06/21/88	1116		98	2X2+1	5	U	F	N					
1013	06/21/88	1428		82	3X4+2	14	U	F	N		MC	MC	12.5	
1013	06/21/88	1811		82	3X3+1	10	U	F	N		MC	MC	13.1	
687	07/12/88	1205	10	98	3X4	12	U	F	Y	26	MC	MCB	11.5	4.9
687	07/12/88	336	10	164	2X1	2	D	F	Y	56				
1013	07/12/88	1145	45	82	3X4	12	U	F	Y	197	MC	MC	11.5	11.9
484	07/12/88	1152	43	262	3X4	12	U	F	Y	197			4.9	4.6
687	08/04/88	2220	10	164	3X5	15	D	F	Y	49	MC	MCB		
761	09/20/88	950	3	98	3X3+2	11	U	P	Y	no movement		MCB	8.9	7.5
88	11/01/88	1100							N		MCB			
888	11/01/88	1102							N		MC			

[1] Habitat designations: MC=Main Channel, MCB=Main Channel Border